SOCIAL ACCEPTABILITY OF WEARABLE TECHNOLOGY USE IN PUBLIC: AN EXPLORATION OF THE SOCIETAL PERCEPTIONS OF A GESTURE-BASED MOBILE TEXTILE INTERFACE

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SOCIAL ACCEPTABILITY OF WEARABLE TECHNOLOGY USE IN PUBLIC: AN EXPLORATION OF THE SOCIETAL PERCEPTIONS OF A GESTURE-BASED MOBILE TEXTILE INTERFACE

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SUMMARY

Textile forms of wearable technology offer the potential for users to interact with electronic devices in a whole new manner. However, the operation of a wearable system can result in non-traditional on-body interactions (including gestural commands) that users may not be comfortable with performing in a public setting. Understanding the societal perceptions of gesture-based interactions will ultimately impact how readily a new form of mobile technology will be adopted within society. The goal of this research is to assess the social acceptability of a user's interaction with an electronic textile wearable interface. Two means of interaction were studied: the first was to assess the most acceptable input method for the interface (tapping, sliding, circular rotation); and the second assessment was to measure the social acceptability of a user interacting with the detachable textile interface at different locations on the body. The study recruited participants who strictly identified themselves as being of American nationality so as to gain insight into the culture-specific perceptions of interacting with a wearable form of technology.

CHAPTER 1

INTRODUCTION

GOALS OF THE STUDY

This study seeks to assess the social acceptability of interacting with a mobile, textile-based on-body input device. Advancements in electronic textiles have allowed for new prospects regarding the development of smart-clothing systems. Nevertheless, the feasibility of pragmatic wearable technology implementation is still in its infancy. Wearable technology, in-line with the mission of mobile computing, supports diversification of computing device platforms for increased functionality and services while in transit [1]. However, these new interface systems are inevitably accompanied by new gesture interactions - most of which are unfamiliar to, and must be learned by, consumers. Determining which interactions will be adopted will largely be driven by how appropriate those actions look and feel when performed in a public setting.

With mobile technology trending toward more compact and seamless form factors, interaction techniques must be designed to support usage in transit. The role that social acceptability plays in terms of gesture indoctrination is a corresponding factor. To date, attention has been given to exploring these interactions and their perceived level of acceptability for various mobile technology applications, such as, hands-free device operation, hand-to-screen manipulation, and novel gesture-control techniques [2]. However, understanding the perceptions that result from interactions that occur with an on-body device has little precedent. This question deserves exploration.

This study seeks to investigate this question using a wearable, textile, control interface (Jogwheel) developed by the Contextual Computing Group at the Georgia

Institute of Technology. This device represents a potential mobile system that can be integrated into clothing and used to operate an external mobile device, such as a cell phone or mp3 player.

This study evaluates the societal response generated by observing interface usage at:

1. seven on-body locations: wrist, forearm, shoulder, collarbone, torso, waist, and front pant pocket; using,
2. three gesture techniques: tapping, sliding, and circular motion.

This study seeks to retrieve robust data regarding appropriate body placement and gesture usage of interacting with a wearable controller in a public setting. This is of relevance as a significant portion of time spent interacting with technology is done in public. Understanding how usage of a wearable system is perceived will largely be a result of how socially acceptable the resulting behavior is. Due to the fact that social norms [3] and practices are culturally defined [4], this inspection was deployed strictly in America to garner insight into the implementation of a wearable system on a culturally specific-basis.

SIGNIFICANCE OF THE PROBLEM

As technology becomes more prolific in our daily lives and supports more of our day-to-day activities, there will be a demand for that technology to be with us at all points in time. For this to occur, technology needs to be designed so that it is portable, easily accessible, and multi-functional. While these factors are essential for product adoption, an equally significant, and often overlooked, criterion is the social ramification of interacting with that product. A noteworthy example is the Bluetooth headset. Praised for its portability and efficacy at hands-free communication, the Bluetooth headset received a significant negative social response due to the uncustomary interaction habits that resulted from product usage [2]. Thus, it is believed that identifying early on what constitutes socially acceptable conduct between a user and a product can help deter negative societal reactions of newly introduced technologies.

This quandary translates over into wearable technology as this platform supports the development of more mobile systems that will be accompanied by novel gesture techniques for system operation. Defining these interactions will largely fall to the responsibility of industry, yet the social appropriateness of these interactions may not be apparent until the product is deployed and in use. Thus, industry can benefit by identifying beforehand where and how individuals will want to use these novel systems to help understand the feasibility of product implementation and adoption.

CHAPTER 2

BACKGROUND INFORMATION

A BRIEF INTRODUCTION TO UBIQUITOUS COMPUTING

In 1988, Mark Weiser, former director of the Computer Science Laboratory at Xerox PARC, coined the term "Ubiquitous Computing" [5]. He envisioned a world where computing devices evaporated into the background, enhancing our interactions with our surroundings and supporting our daily activities [5]. Soon thereafter in the mid-90s, the Wearable Computers Group was formulated within the Media Lab at the Massachusetts Institute of Technology. The line of thought within this group was that technology should not be integrated into our surroundings (requiring the user to depend on the environment), but that technology should be conveniently located on the body so that it would move with the user [5].

This schism in thought led to a divergence of computing applications. Ubiquitous computing was implemented in contexts of the home (smart home), workplace, and classroom, while wearable computing was employed on the body in compact, mountable, and mobile form factors (heads-up displays or wristwatch computers). Years later, the emergence of the smartphone, with its computing power and multi-functional capabilities, marked the first realized piece of mobile technology that truly represented the vision of wearable computing.

The smartphone is also a platform that has now allowed for the ubiquitous computing and wearable computing paths to overlap [6]. For example, smartphone functionality encompasses the ability to sync to other technologies in the home while allowing the operational cues to be performed from a remote location. As such, the smartphone is paving the way for a truly technologically-enhanced environment. Research institutes around the world are continuing to push the envelope by exploring novel forms of mobile and wearable technologies with respect to nanotechnology, electronic textiles, chemical engineering, and much more[7]. These technologies are being produced in labs across the world, but now face the challenge of being presented in a usable form to society.

This research will be an exploration into this very consideration. Understanding the societal perceptions that accompany new forms of technology will shed insight into the feasibility of wearable technology acceptance and help lay the groundwork for future developments in wearable computing devices.

WEARABLE TECHNOLOGY

"The term 'wearable technologies' (also dubbed 'wearables'), refers particularly to the electrical engineering, physical computing, and wireless communications networks that make a fashionable wearable functional" [7]. The first known wearable piece of technology is the popularized wristwatch. The wristwatch has an extended history of transformation from a stationary time-keeping device to a compact and fashionable mobile timepiece [8]. The necessity of proper time keeping, the convenience of an on-body system, and the customization of this wearable as an aesthetic jewelry piece has enabled the wristwatch to develop as a common, and accepted, form of wearable technology. The factors of size, accessibility, and portability, combined with fashionable qualities, helped set an essential precedent for the advancement of wearable computing.

Wearable computing differs from wearable technology in that the former refers to those technologies that specifically support and perform complex computations, creating a constant level of operational and interactional behaviors [7]. The latter extends to encompass the full gamut of wearable types of devices, whether electrically driven, mechanically driven, chemically driven, or more. Challenges in wearability that have arisen from more mechanically operated forms of wearable technology, such as the wristwatch, will inevitably draw parallels with the progression of current mobile and ubiquitous computing devices as pertinent design considerations revolve around aesthetics, body placement, interface design, and societal impact [8]. With respect to these characteristics, the history of the wristwatch can be a serviceable example for the advancement of wearable computing platforms. Figure 1 shows the first wearable computer in use - a cigarette-pack sized computing device and ear piece used to count roulette revolutions to predict the landing position of the ball [9].

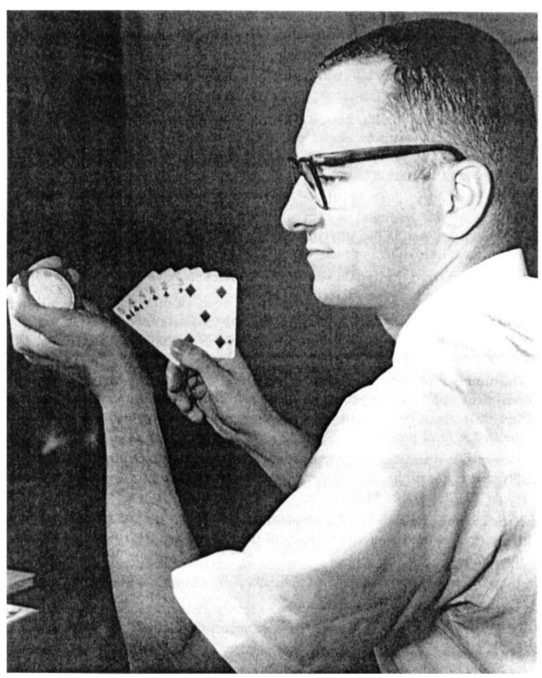


Figure 1. The first wearable computer - invented by Ed Thorp and Claude Shannon in 1966 [9]

MOBILE AND UBIQUITOUS COMPUTING

Wearable computing lies within the larger division of mobile and ubiquitous computing platforms. Mobile and ubiquitous technology are characterized as being small, robust, embeddable or portable computing devices that support one's day-to-day interactions [5, 1]. The foundational work in this arena, pioneered by Xerox PARC in Palo Alto in the early 90s, explored a range of computing devices at different designated sizes: inch, foot, and yard. These metrics were devised to physically define the minimum set of computing devices needed to encompass a broad scope of functional applications [5]. These units resulted in the development of three product forms: the Tab (inch), the Pad (foot), and the Liveboard (yard) [5]. These scales set the precedent for current technologies on the market, and are reflected in items such as the cell phone, the tablet PC, and Smart Board, respectively.

Inch-scale computing devices laid the groundwork for wearable computer exploration. Heads-up displays were highly popular during the early days of the MIT Wearable Computers Group as they were some of the first computing devices that were truly wearable in nature. Figure 2 depicts Professor Thad Starner of the MIT Media Laboratory wearing a heads-up display integrated into his glasses, and operated by the Twiddler, a one-handed chorded keypad that can fit into the pocket [5].

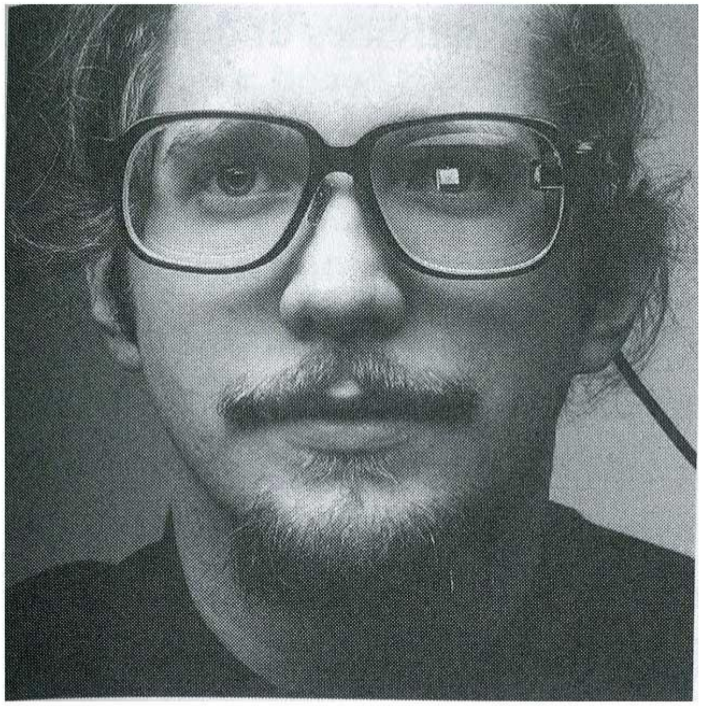


Figure 2. Professor Thad Starner from the MIT Media Laboratory [5]

Heads-up displays served as precursors to the more powerful and unobtrusive mobile computing devices used in this day and age, e.g. smartphones. In fact, the most common ubiquitous computer used within society today is the cellular phone [5]. Its compact size and light weight nature permit for these devices to be highly mobile, granting individuals the ability to have a powerful computing device with them at all times. While smartphones support the original capabilities of the heads-up display, they are more accurately classified as a form of mobile technology as opposed to wearable technology. Their size qualifies them as portable devices which afford wearability since they can be carried in pockets, purses, etc.; however, the cellular phone itself is not truly wearable.

Other forms of commonly used mobile and wearable computers found on the market today include mp3 players, Bluetooth headsets, cameras, tablets, laptops, handheld video games, and health and location monitoring systems. From the aforementioned list, one can see that very few of these items are genuinely wearable

While the available types of portable technology on the market are compact in size, most of the current forms of mobile technology are not designed in a manner to be easily worn on the body or integrated into clothing. The typical form factor of today's portable technology (cell phones, mp3 players, laptops) boasts hard-cased exteriors that are married with cases or appendages that offer some sort of 'wearability' feature. Examples include laptop cases, workout armbands for phones or mp3 players, and phone holsters that clip onto the belt buckle or pocket. Future work to be done in this arena is left to making these items more wearable, that is, creating portable items that can be easily integrated into clothing while still being comfortable for the wearer [10].

FASHION, COMPUTERS, AND SMART TEXTILES

As exemplified by the wristwatch, fashion plays a significant role in contributing to the social acceptance and continued use of a wearable form of technology [8]. The textbook 'Fashionable Technology' defines a fashionable wearable as "'designed' garments, accessories, or jewelry that combine aesthetics and style with functional technology" [7]. Combining technology with new materials permits for computing devices to take on new appearances and forms, changing the way we interact with these devices as well as our attitudes toward this technology in general [11], [12].

On a functional level, the goal of wearable computing is to exploit novel methods and materials to incorporate electronics into clothing in a more seamless manner [10]. Non-traditional conductive materials, such as conductive thread, fabric, and Velcro permit for such inventive integration and prototyping. In 1998, Maggie Orth, Rehmi Post, and Emily Cooper from the MIT Media Lab, presented some of the first exploratory work regarding textile-based wearable technology platforms. It was realized that structurally the “thread-up and thread-down of the (textile) weaving process corresponds to the 0 and 1 binary logic of computer circuitry” [7]. This set the stage for information processing techniques that could be incorporated into clothing [13]. Capitalizing on such underpinnings, Orth’s, Post’s, and Cooper’s work investigated the integration of conductive textiles and novel construction techniques to make functional, fabric-based input technologies such as the quilted keypad shown in Figure 3 [11].

Figure 3. Quilted keypad [11]

Some equally novel smart-textile forms being explored around the same time were the wearable motherboard (Figure 5) at the Georgia Institute of Technology [13], the Musical Jacket [11] and Firefly Dress (Figure 4) [14] at the Massachusetts Institute of Technology, and the Electric Suspenders (Figure 5) at the Aerospace Corporation in El Segundo, California [15].

Figure 4. Firefly dress developed at MIT Media Lab [14]

These novel interfaces created new modalities for experiencing technology. In addition to the exploratory and fashion-oriented work of electronic textiles, the potential for these technologies to create new and serviceable industry-specific prospects helped wearable technology garner significant appeal. The direct applications were most prominently envisioned in the areas of healthcare, law enforcement, and military, as well as recreational and entertainment purposes [13].

Figure 5. Wearable motherboard designed as a bullet detection vest for the Navy by Georgia Tech (Left) [13], and Electric Suspenders developed at the Aerospace Corporation (Right) [15]

Contextually driven wearables led to fabrication research that focused on manufacturing and production techniques for smart textiles [13]. Smart textiles, or electronic textiles, are fabric-based materials with conductive properties in them. Items such as conductive thread and conductive fabric (Figure 6) are generally made from cotton or polyester fibers that are metal plated. They look and feel very similar, if not exactly like regular textiles, and can be used in sewing and embroidery machines like non-metallic textiles. To date, smart fabrics have found a permanent home in industrial trades that require wearable conductive materials for electromagnetic radiation shielding, such as electrical engineers who work on radio frequency equipment.

Figure 6. Conductive thread (Left) and conductive fabric (Right) [16], [17]
http://blog.craftzine.com/archive/2009/03/conductive_thread_overview.html
http://www.tradekorea.com/products/Conductive_ Fabric.html

Throughout the decade, significant advancement has been made in wearable technology production to also bring these items to consumer markets. A current example of a functioning wearable computing device is the Kenpo iPod Jacket as shown in Figure 7 [18].

Figure 7. Kenpo iPod Jacket with fabric control buttons in sleeve [18]
http://hight3ch.com/kenpo-ipod-control-jacket/

While this wearable item demonstrates that this technology has already been made available for consumer use, significant progress must still be made with respect to manufacturing and maintenance (washability, power, breakage) aspects before this technology can become pragmatic within society. Dr. Thad Starner and Instructor Clint Zeagler at the Georgia Institute of Technology have developed the Swatchbook, an electronic textile and graphical user interface template to explore these very fabrication issues [19].

Dr. Leah Buechley, director of the High-Low Tech group at the Massachusetts Institute of Technology, has devoted much of her work to developing construction techniques and novel interface methods between electronics and textiles. Dr. Buechley champions the do-it-yourself approach and looks at craft and sewing techniques as a way of educating individuals about electronics. She is widely recognized for developing the e-textile construction kit (Figure 8) and the Lilypad Arduino (Figure 9), which encompass more seamless ways of infusing textiles with technology.

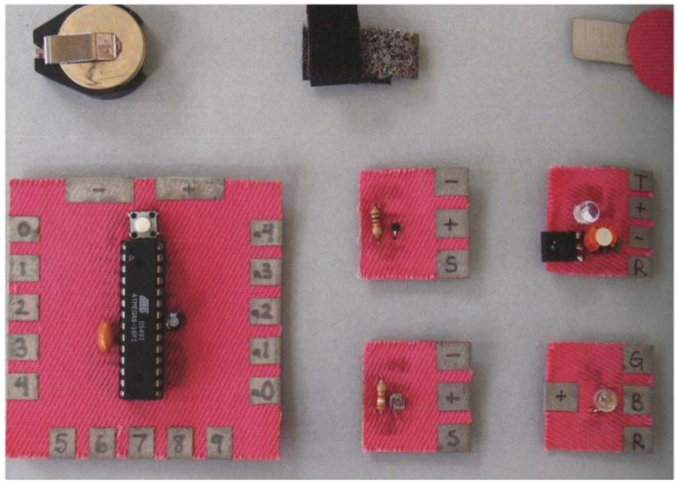


Figure 8. Dr. Leah Buechley's e-textile construction kit [7]

Figure 9. The Lilypad Arduino (Right) with embroidery weave (Left) [20], [21]
http://blog.craftzine.com/archive/2010/12/lilypad_arduino_projects_video.html
http://www.talk2myshirt.com/blog/archives/315

These advancements in wearable computing platforms have led to an array of initiatives that look at the complex interaction between fashion, textiles and computers. This work continues around the globe at institutions such as the University of Bremen, the University of Australia, Parsons The New School for Design, Newcastle University, and the Interactive Institute to name a few [7]. Many of the fashion-oriented developments in this arena use the concept of wearable technology as a muse to develop garments that explore our physical relationships to our surroundings, generating wearables that respond to both internal and environmental cues. Figure 10 depicts the kinetic Skorpion dress that moves on the body and distorts its shape [7], and the Bubelle dress on the right is a chromatic representation of the wearers emotions [22].

Figure 10. Skorpion body wear (Left) [7] and Philip's Bubelle dress (Right) [22]
http://www.infoniac.com/hi-tech/top-6-high-tech-dresses.html

RELATED WORK

WEARABLE TECHNOLOGY CONSTRUCTS

Understanding the requirements conducive to wearable technology adoption is of extreme significance as it will shed light on the development of wearable technology solutions. Beginning in the mid-1990s, identifying the platforms for effective wearable technology implementation began to be critically assessed. While still in the exploratory phase, research-to-date has found that for wearable technology to be successfully adopted, its body placement has to support a number of conditions. Namely, it must be accessible, wearable, stable, convey information in an effective manner, and be socially acceptable [23].

Accessibility

Accessibility refers to the respective access times of a piece of wearable technology worn at different points on the body. According to Dr. Thad Starner, wearable computing suffers if it does not adhere to the two-second rule, a rule stating that if it takes longer than two seconds for a user to take out one's mobile device and turn it on then users will be less inclined to interact with the device [24]. Inconvenient placement of technology will result in prolonged access times [25], and previous research confirms that "the amount of time it takes to access a device has a strong influence on whether a user will actually use that device at all [26, 27]. Thus, to ensure ease of operation for the user, it is vital that wearable technology that supports constant interaction be placed at points on the body that are comfortably within reach and easy to activate. In contrast, the device should not be so accessible that it produces an inordinate amount of false triggers [28].

Thus, precautionary measures should be taken so that the system is effective, yet not overly sensitive to accidental activation.

Wearability

For a piece of wearable technology to be adopted it must also support 'wearability'. This construct refers to the need for a wearable item that is, but not limited to, comfortable, small in size, accessible, unobtrusive, and light in weight [13]. Gemperle et al. [29] and Hudson et al. [23] explored successful on-body placement of wearable technology and determined that human dynamic anthropometric data, as well as the type of activity that the wearable supports, will largely drive the form and placement of the wearable. For a full list of Design Guidelines for Wearability, please see Appendix A.

Stability

Additionally, for a wearable piece of technology to be effectively worn, construction must be sound. Hence, the physical state of the wearable must exhibit strength, durability, flexibility, [11] and stable electronic integration [23].

Effective Information Conveyance

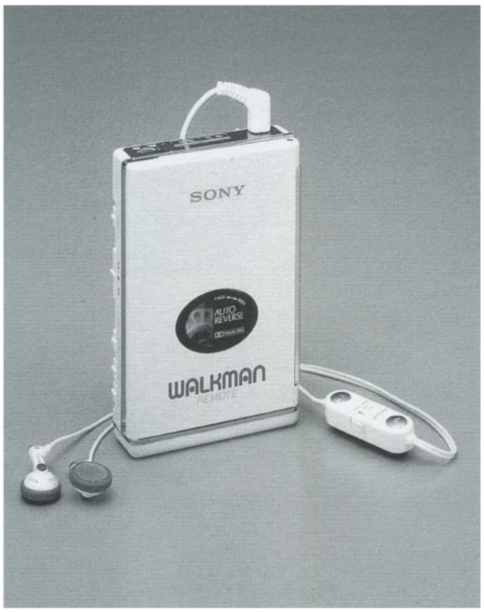
Furthermore, for wearable technology to be useful, it must be effective at conveying the appropriate information. Hudson et al. looked at the reaction times of individuals using a wearable visual feedback system [23]. The findings suggested that receptiveness to the various visual cues was a direct result of system body placement and the types of physical activities that permitted for effective line-of-sight. If the system is not designed for constant visual attention, then alternative sensory forms of feedback should be employed. Vibro-tactile feedback or auditory cues, such as those commonly employed by cellular phones, can serve as effective output modalities used in eyes-free scenarios.

Social Acceptability

Social acceptability involves the social skills and the presentation in which one comports himself/herself in order to interact comfortably within society, or, to not embarrass or call attention to oneself [30]. Clothing falls naturally into this category as, within cultural settings, there are outfits deemed ‘appropriate’ or ‘inappropriate’ for particular social situations. Examples of situational-based inappropriate attire would entail wearing a bathing suit to a corporate meeting, or wearing pajamas in a school environment. The implementation of wearable technology will follow similar conventions, as integrating electronics into clothing will result in new designs, take on new shapes, and principally require novel interactions for operation. Developing these systems successfully will be subject to the level of social acceptability they assume. This notion is of principal importance for this study and will thus be the underlying condition of which this research will focus. The construct of social acceptability, as well as related work of social acceptability with respect to technologies, will be expanded on in this paper.

SOCIAL ACCEPTABILITY OF INTERACTING WITH MOBILE TECHNOLOGY

Malhotra and Galletta ascertained that social influences will have a large impact on system usage and acceptance behavior toward new technologies [31]. In 1979, the Sony Walkman debuted as the first portable music playing device. It revolutionized the way we listened to music; however, the developers knew that this product would face dissonance as the concept of wearing headphones and walking around with a portable electronic device was entirely foreign. To supersede this, marketers advertised heavily with fashion models, generating a cultural phenomenon that made the wearing of this device fashionable. This helped to supplant any social discord with the notion that use of this product was hip, or acceptable [4]. Figure 11 display a Sony Walkman and the type of commercial advertising Sony used to promote their product.



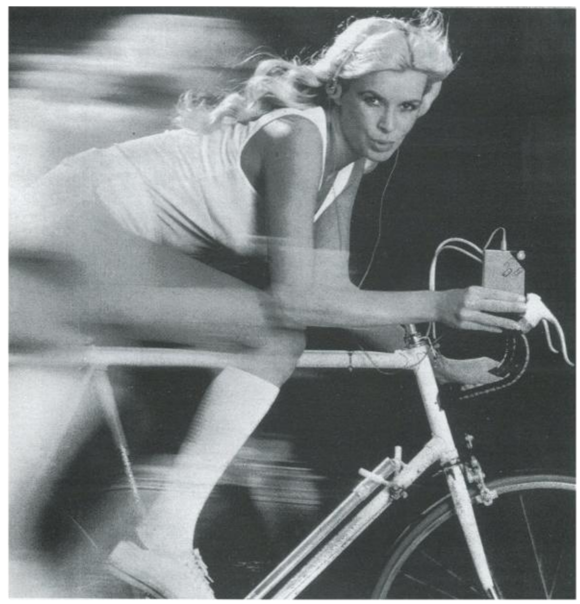


Figure 11. Sony Walkman (Left) and model advertisement (Right) [4]

As such, the advent of wearable computing affords technology that is more portable and accessible in nature, providing information that is available at our fingertips. However, these technologies will present themselves in new form factors, and interface designs will be accompanied by a set of gesture interactions or usage techniques that individuals may or may not be willing to perform in either a private or public setting. They will, without a doubt, face some of the same barriers to entry as exhibited by the Walkman, and establishing societal acceptance at large will be a driving factor for the success of future wearable technologies.

Rico et al. explored the social acceptability of novel gesture types to control a mobile phone [32]. This research was then extended to look at the social acceptability of gesture-based interactions with respect to a specific context (public setting, home, workplace, etc) [2]. The results indicated a strong significance between willingness to perform a particular gesture interaction and audience/location [2]. This indicates that gesture types (which are a byproduct of the challenges of overall interface design) require a higher level of scrutiny if they are to be acceptable for use within a public context.

While current research has looked at the social acceptability of gesture-based mobile control techniques [32], [2] as well as the feasibility of hands-free mobile control techniques (e.g. head-tilting, foot tapping, EMG controllers, and wrist-tilting) [33], [34], [35], [36] few studies have been conducted to assess the third-party social acceptability issues that arise from interacting with a mobile system when it is located directly on the body.

DeBlasio and Walker looked at patients' perceived quality of care while interacting with a doctor supported by a wearable note-taking apparatus [37]. Holleis et al. assessed the perceptions of interacting with textile interfaces of varying conspicuousness and their preferred body locations [28], and Karrer et al. looked at a users' reaction to an eye's free textile volume changer [38]. While this research touches upon the social acceptability of wearable input methods, none of them address acceptability in a widely public setting or from an objective third-party perspective. As with any newly developed system, wearable technology will be accompanied by new interactions for operation. Interactions unfamiliar to current social institutions will either be abandoned due to negative societal reactions, or they can become learned and accepted by continued use and familiarity. Novel gestures for Apple products, such as swiping and tapping, have been widely adopted as these are practical interactions that support a highly useful product.

A noteworthy example of an adopted unfamiliar mobile device is the Bluetooth headset. The Bluetooth headset is a socially uneasy mobile device because it provides for interaction with limited contextual feedback, i.e. it will appear awkward when someone talks to the air in public, especially if one cannot see the device being worn on the ear. In the case of this headset, however, function (value of a hands free communication device) outweighed public discomfort, and the Bluetooth headset is still widely used to date. This example also demonstrates how the degree of acceptance changes with the level of exposure to a certain technology. Watching a person communicate on a Bluetooth headset still looks relatively unnatural, however, it is fair to say that because it has remained in society for such a prolonged amount of time, the general public is familiar with the device and more accepting of its usage [2].

CHAPTER 3

STUDY DESIGN CRITERIA OVERVIEW

SOCIAL ACCEPTABILITY PREMISE

There are many key elements to this research that are dictated by society: clothing, gestural behaviors, as well as technology usage and interactions. Such factors are pervasive [13], meaning they are constants in society and thus will play a substantial role in the adoption of wearable technology.

Social acceptability extends back to meaning formulation, where societies at large would assign meaning to different activities to make sense of them [4]. As such, different regions can easily develop a unique set of attitudes toward social behavior, making social acceptability culture-specific. This research recognizes how culture can directly influence new product adoption, which is why this study screened individuals so that only attitudes of those who identified of American nationality would be captured. Such causal links between culture and usage behavior are the very reason companies design different products for different countries. This premise serves as a solid foundation for future technology assessment.

It is also recognized that what is deemed socially acceptable can, in fact, change. This is particularly true of new fashions and technology. Thus, this research can also serve as a forerunner to understanding types of new technologies and usage behaviors consumers will find useful enough to adopt and, resultantly, adapt to.

A WEARABLE CONTROL SYSTEM

Electronic forms of wearable technology have been present in society for the past 40 years. The timeless examples include the digital wristwatch, introduced in 1972, [39] and the Sony Walkman, introduced in 1979 [4]. The advent of these technologies has helped pave the way for a slew of portable electronic devices up to the present day - the cell phone ultimately becoming the most ubiquitous of all portable devices [5]. Such a desire for portable technology denotes a potential market for wearable technology; however, the different types of wearable devices currently on the market are somewhat limited.

The mobile, textile, controller interface used for this study seeks to evaluate a new class of wearable systems that combines technology and fashion using electronic textiles. This innovative development in wearable technology promotes a plethora of opportunities for ubiquitous computing. The division between hardware and apparel becomes blurred as electronic textiles and alternative conductive materials allow for a more seamless integration of technology into clothing. Just some of the potential uses include interfacing with a cell phone, mp3 player, or other electronic device. However, the implementation of a wearable device is also accompanied by a corresponding number of challenges. To be a textile-based wearable system, the device is required to have a number of wearability and usability features that naturally depend on the intended application. Ideally the device must be minimally intrusive, easily accessible, light weight, compact, aesthetically pleasing, washable, and easily rechargeable with minimal heat dissipation. A wearable system will also be subject to usage behavior of which this research looks to explore.

Just as mobile technology research has investigated the use of pre-established gestures for novel operation methods, wearable forms of technology can look to explore common gesture to clothing interactions as a means for discreet, and as a result, less awkward operation. Fiddling with a shirt collar or pushing up one’s sleeve are natural forms of interaction that one may have with his or her attire. On a related note, wearable technology could capitalize on similar gestures to control electronic devices (e.g., pushing up a sleeve to increase volume on a MP3 player, or brushing your pant pocket to answer a cell phone call). Looking at how our interactions with wearable technology can become seamless yet remain effective (avoiding accidental triggers or unintended operations) is cause for future research.

While a number of different textile-based input devices exist, this study has chosen to focus on an embroidered wearable control interface for interaction evaluation. Such an interface can be embroidered directly into the garment, making it exposed and highly visible to the public (such as the input controls displayed in the Kenpo Jacket). The conspicuousness of the interface, as well as the positioning of the system, will explore a type of usage behavior that deserves evaluation in its infancy. The Jogwheel will be evaluated with this in mind. Advantages of the Jogwheel are that it is an embroidered, aesthetic interface that can be likened to a brand emblem or design. This is representative of the direction that this technology can take – customizable and aesthetic control interfaces that can remain conspicuous without calling attention to its intent.

Much of the work done at the Georgia Institute of Technology, the Massachusetts Institute of Technology, as well as in the greater design community, is helping to lead the way with respect to customizable e-textile interfaces. Dr. Leah Buechley at MIT explores novel electronic and fabric integration methods. Her work also looks at utilizing current clothing adornments (snaps, fasteners) as circuit connection points [40]. This work will help push soft circuit construction as well as increase the ability to design wearable pieces that are simultaneously aesthetic. Interface customization is a focal point at the

Georgia Institute of Technology where embroidery techniques are used for making tactile, e-textile interfaces that are both functional and aesthetic. This led to the creation of the Swatchbook [19], and ultimately the development of the Jogwheel used for this study.

JOGWHEEL

Figure 12 depicts the wearable textile controller interface used for this study. It was created by the Contextual Computing Group at the Georgia Institute of Technology. Fabrication entailed the use of conductive thread, non-conductive thread, non-conductive cotton fabric, and interfacing. The pattern was constructed using a Brother Embroidery machine. The pattern, referred to as a Jogwheel, was devised to represent the tangible version of an iPod click wheel with fairly similar operation techniques.

Figure 12. Electronic textile controller interface (Left) and prototype (Right)

The embroidered thread creates a raised surface topography (as depicted more clearly in the prototype photo) that helps guide one’s finger along the embroidered path. The Jogwheel is two times the diameter (3 inches) of a traditional iPod click wheel (1.5 inches). The Jogwheel is larger in size to allow for greater accuracy and increased functionality. This design was selected from two other designs, a slider and a menu system, because it allowed for the three types of gesture interactions under evaluation: tapping, sliding, and circular motion. The system uses resistive-capacitive sensing to determine when it is being touched. It works when a user places his or her finger on the device so as to connect the outer ring and inner pads, completing the circuit.

Realistically, this system was devised to be integrated into clothing in a two part system. The surface is the interface system, and the underside is powered through a network of leads (shown in Figure 13), also constructed using conductive thread. This, in effect, would be a fully developed smart fabric control system ready for apparel integration. For the purposes of filming the controller in use on multiple body locations, only a prototype of the Jogwheel controller was used for the study. Sounds effects were used to simulate a phone ringing that the controller was then used to silence. The controller was attached to the various body positions using an adhesive backing, which allowed for easy relocation of the system at various points on the body. For a realistic wearable controller, it is most feasible to either have the device permanently integrated into an item of closing, or to have a pin type stand alone system that can be removed and fastened onto multiple clothing items.

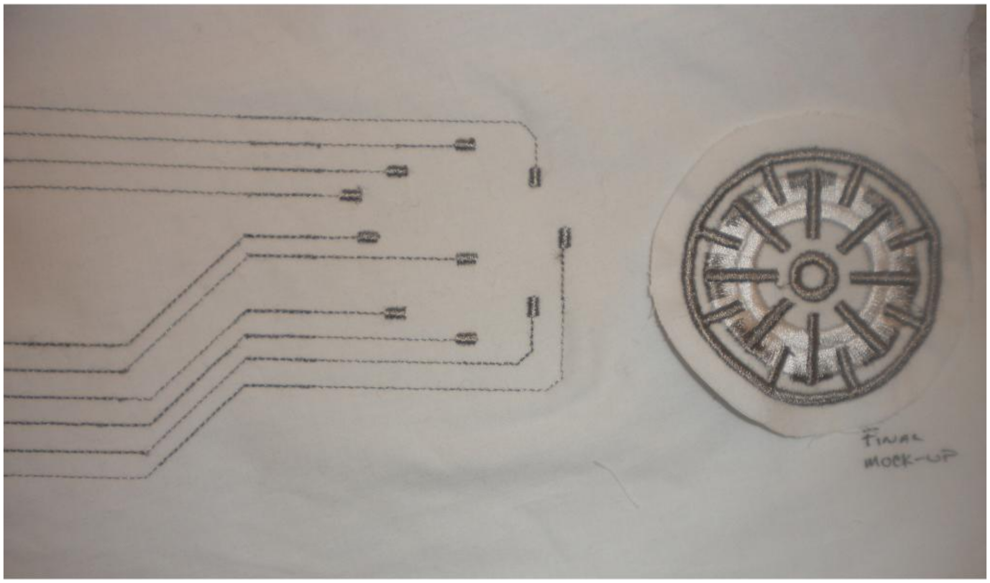


Figure 13. Jogwheel with lead network for functional interface

BODY PLACEMENT

Body placement of the wearable system was discussed critically to ensure that a significant number of locations on the body were selected for assessment. The goal was to include body points that would capture a range of emotional responses. One objective of this study is to assess the body position for a wearable device that is the most socially accepted, or rather, which generates the least negative social response. Drawing from previous research (Gemperle et al. and Hudson el al.) of feasible wearable technology body placement (depicted in Figure 14) [23], [29] as well as discussions with Dr. Thad Starner and members of the Contextual Computing group at the Georgia Institute of Technology, seven on-body positions for system evaluation were selected.

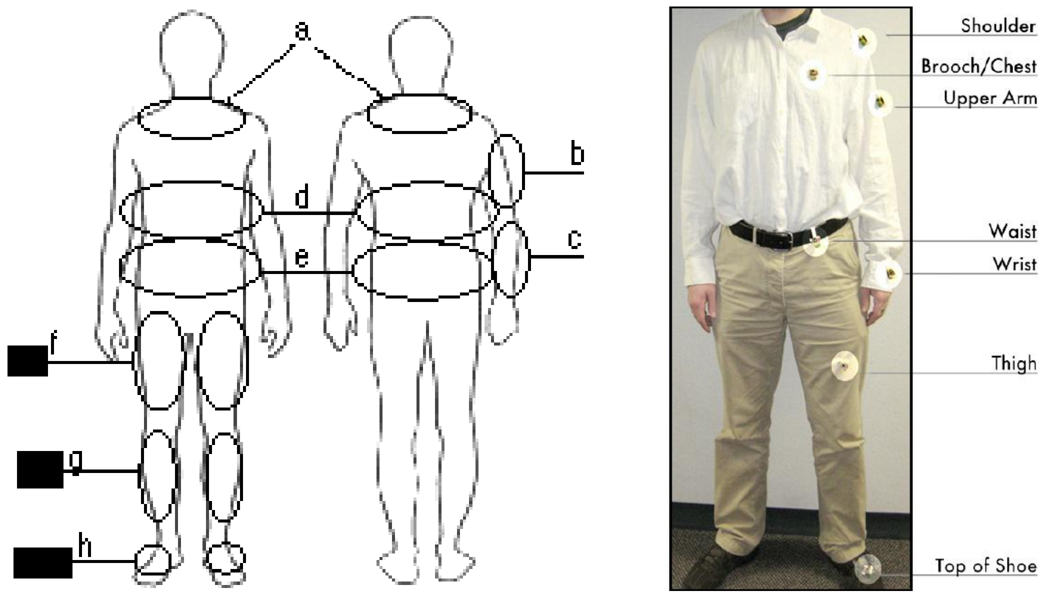


Figure 14. Previously explored on-body locations for wearable technology [23], [29]

Figure 15 demonstrates the seven on-body locations selected for controller placement for this study. They include: wrist, forearm, shoulder, collarbone, torso, waist and front pant pocket. Locations on the lower extremities, such as the feet and lower leg, were not considered as the system had to be within one arms length of comfortable reaching distance.

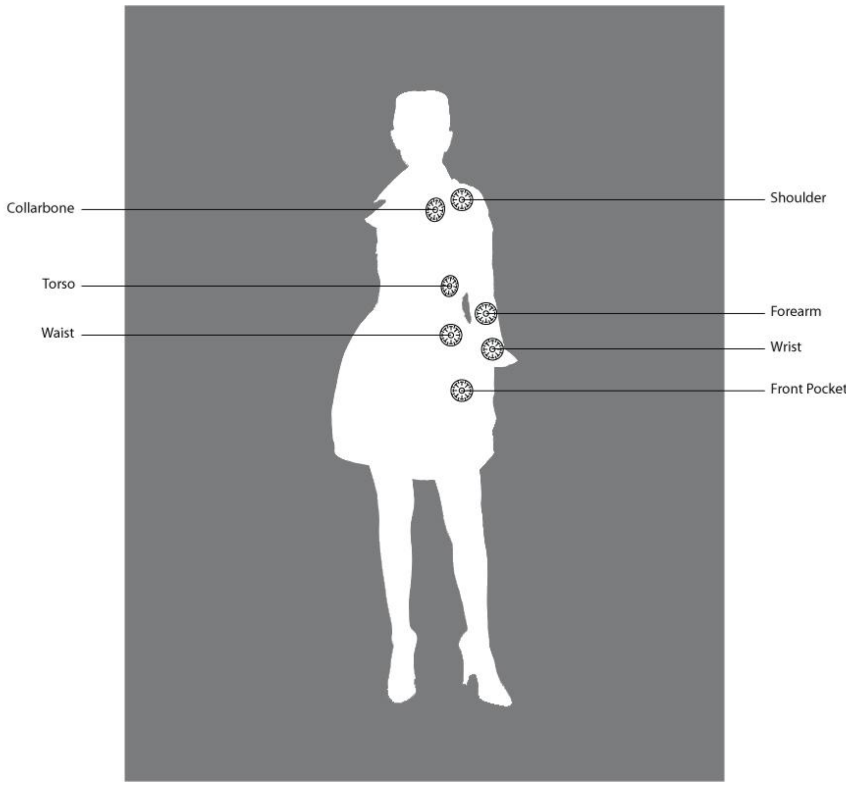


Figure 15. Body locations for controller placement evaluation

As in the case of the Bluetooth headset, acceptance did not occur immediately, but came later from continued use and societal exposure to the product [2]. It is expected that the textile, wearable controller interface will result in similar initial cognitive dissonance, as most novel forms of technology introduced to market must go through a gestation period before society will adopt it as a normal, or, recognized, form of technology [4]. In consideration of this precept, it was important to evaluate a large number of on-body locations to ensure that the societal reaction is a result of the actual body placement as opposed to the novelty of the textile wearable controller interface.

The apparel to which the Jogwheel was to be mounted was also given careful consideration, as it was necessary to present the Jogwheel on a non-offensive surface so as to not bias the observer in any way. A long-sleeved, Navy blue shirt was ultimately selected as it permitted for easy interface placement on both the wrist and forearm, and was conservative in nature. Navy blue was selected as it was the color that had no negative associations [41].

GESTURE INTERACTIONS

Within the field of Human-Computer Interaction, the role of gesture-controlled input for device operation has been explored for many different applications, such as PDA system usage [42], virtual reality [43], touch screen manipulation [44], et cetera. Gesture-based input taps into the current practice of communicating intent with hand motions or body movements [45]. This method of communication offers exciting modalities for current technology operation as it has the potential to map our mental-model of gesture semiotics onto our devices, creating a more effortless and intuitive interaction between user and device [46].

Research on table top surfaces revealed that preferred gesture techniques were classified as gesture primitives – simple, and basic hand shapes used for many interaction tasks [47]. This statement supports the techniques (selection, swiping, scrolling, pinching, and unpinching) that are employed today for effective mobile device manipulation. These techniques are exemplified in gesture-operated computing devices such as the iPod, iPhone, and tablet devices. These interaction techniques, while effective, are each accompanied by their respective advantages and limitations. These tradeoffs include speed of operation, productivity, ease of learning [48], and error rate [49]. For this research, three types of similar input gestures were selected for evaluation: tapping, sliding, and circular motion. Such tradeoffs will be discussed in detail with respect to the chosen gesture interactions used for the Jogwheel.

As noted earlier, three types of recognized input interactions were chosen for assessment in this study: tapping, sliding, and circular motion (refer to Figure 16). Each interaction type was selected due to its current use and familiarity within society (tapping corresponds to selection, sliding corresponds to swiping, and circular motion corresponds to scrolling). It is also important to note that the selected gesture interactions were chosen because they can all be performed with the ease of one hand as opposed to two-handed gesture interactions (touch screen texting on a qwerty keyboard) or, hands-free gesture interactions (head tilt).

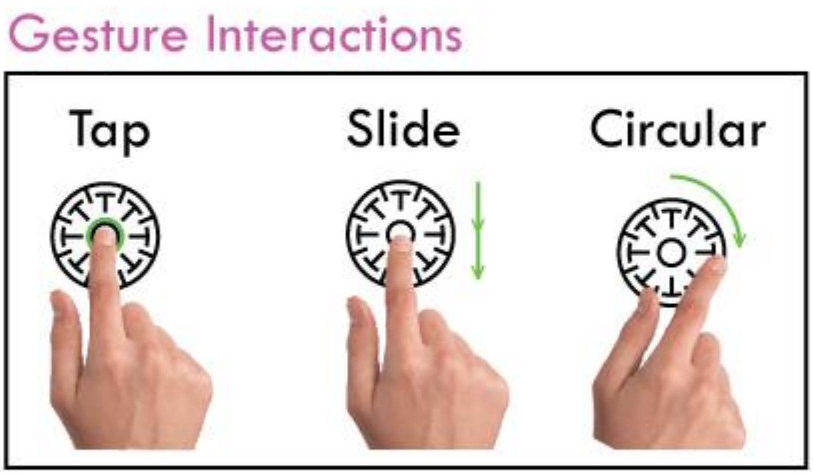


Figure 16. Gesture interaction types explored for the study

These gestures are accompanied by corresponding input capabilities and varying effort levels that impact their level of appropriateness for the intended application. Challenges arise when weighing the technological benefits of one method (multiple menu options) with the socially accepted practice of another method (low effort).

Tapping offers the ability for a quick operational execution with minimal attention demand; however, its limitation lies in the fact that it is an analog system, meaning that for each selection option there must be a corresponding button or depression point. The tradeoff of this design means that the interface will have to be designed either with numerous buttons to support increased functionality, or few buttons which limits extensive interface capability. On the other hand, a scroll wheel has embedded within it the function to access multiple levels, as in the menu interface of an iPod. As such, a scroll wheel interface offers increased function capabilities, but at the potential sacrifice of a quick and error-free operation. This will be discussed further.

Sliding, similar to swiping on an iPhone or other touch surfaces, offers the ability for digital input as in incremental variability as opposed to a binary operation. A combination of tapping and sliding could also offer increased menu operations. However, assessing the acceptability of combination input types will be left for future work. Drawbacks for the sliding interaction include decreased accuracy. This can be a result of the speed of the interaction as well as sufficient contact of the interaction. A slider is also terminating, implying that even if the interface can access multiple levels of a menu system, the physical form factor prevents this action.

The circular motion, consistent with scrolling on an iPod, offers the aforementioned advantage (access to multiple levels of information). However, scrolling is the most prolonged of all the input methods, resulting in slower interaction time and increased user attention. These tradeoffs are very relevant and strictly functional in nature. Assessing the social acceptability of these gesture interactions will add another layer to identifying appropriate interactional methods for wearable and mobile technologies.

PUBLIC SETTING AND CONTEXT

To adequately capture a scenario for an objective third-party audience, it was necessary to portray the study content in a location that would be easily recognized as a public setting. The setting needed to be believable as well as controlled. A number of potential settings resulted from an initial brainstorming session: street corner, elevator, hallway, and supermarket. The elevator setting was deemed the most fit.

While a street corner, hallway, and supermarket all qualified as recognizable public settings, each location was accompanied by a number of variables that could not be controlled, thus lending to the possibility of inconsistent results. A street corner appearance would undoubtedly appear differently in the respective countries (should this research be extended in the future to include multiple cultures), and the light, ambient sound, passersby, and other environmental conditions could not be reproduced. The same bystander problem was apparent in the hallway and supermarket scenario as well. Additionally, should this study be conducted in different countries, a supermarket setting would require filming in a location that appearance-wise looked like a traditional grocery store for each respective country – eliminating the desired controlled environment.

STUDY DESIGN CRITERIA

This research will evaluate the perceived acceptance of a wearable mobile system from a third-person perspective. To gather holistic data on current, culture-specific societal perceptions of gesture-based on-body technology usage, the study will be deployed in survey format in the United States of America. For purity of results, it was crucial to depict the scenario within a controlled setting with fixed ambient features and context. Thus, it was decided that the best way to capture these conditions was to record video footage of the interaction and present the study in an online survey that could easily be disseminated cross-country. The audience served as the objective viewing party that watched video footage of a user's interaction with the on-body textile, wearable controller. Each video of an individual interacting with the on-body system was recorded using a native born male and female actor speaking in English, the official language of the United States of America.

HYPOTHESES AND RESEARCH QUESTIONS

In an effort to better understand societal attitudes towards gesture-based interactions for operating a mobile device, as well as the feasibility of interacting with a wearable electronic interface, this research will seek to answer two questions:

1) What is the most acceptable location on the body for placement of a wearable device?
2) What is the most acceptable gesture for information input on a wearable device?

The acceptability results of the two conditions may differ depending on a variety of factors, including: culture bias, participant age, gender roles, current attitudes toward technology, as well as personal familiarity with technology. From this, one can form a series of hypotheses regarding the outcome of gesture-based technology. The hypotheses are divided amongst the respective research questions:

1) What is the most acceptable location on the body for placement of a wearable device?
    - HI) Participants will define a set of body placements for acceptable locations of the textile-based wearable controller.
    - H2) The wrist and forearm will be the most acceptable body locations for interface placement.
    - H3) The acceptability ratings of controller body placement will differ based on the gender of the performer.
    - H4) The preference of controller body placement will differ based on participant gender.
2) What is the most acceptable gesture for information input on a wearable device?

H5) Participants will define the most preferred input gesture for a wearable controller.

H6) Input gestures that demand a perceived level of minimal attention will be preferred.

H7) Input gestures that are quicker to perform will be preferred.

CHAPTER 4

METHODOLOGY

STUDY PARAMETERS

This study was interested in assessing the societal perceptions of wearable technology interactions. Due to the fact that social acceptability is culturally driven, it was important that the direction of the study be country-specific. As such, this research was conducted in the United States of America to capture American attitudes toward on-body wearable technology usage.

This study sought to capture the third-person perspective of interacting with a textile control interface worn at different points on the body. The study was designed to be a within-subjects study (50-70 participants). The goal of the survey was to collect opinions on the viability of 3 gesture types at 7 different on-body locations at 2 views (4-5 feet away, and ~ 1 foot away) on both a male and a female actor.

Participants in the study were asked to respond to 11 acceptability questions for each video at each on-body location. Every question was presented as a 5-point Likert-scale with ratings from strongly agree to strongly disagree.

SURVEYING

Surveying has a number of advantages. Namely, it can reach a broad audience, and it permits participants to conduct the study at their own leisure in the comfort of a private environment, thus capturing a higher level of honesty in participant responses. The survey method was chosen because of the large scope of the thesis as it facilitated easy dissemination, large-scale data collection, and supported multiple viewing options in a controlled manner (similar to that of Rico et al. [2]). SurveyGizmo.com, an online survey and questionnaire service, was used to develop the research survey.

SurveyGizmo.com was chosen as it offered enhanced control settings, video and image compatibility, and supported multiple languages. Participants were recruited via word of mouth and through electronic advertisements.

SURVEY STRUCTURE

The survey content was structured to retrieve fair and unbiased quantitative data. The entire survey consisted of a demographic questionnaire, the wearable technology acceptability questionnaire, and an exit questionnaire. The acceptability questionnaire was developed to ask a series of evaluative questions assessing the third-person perspective of an individual interacting with a wearable device. In this study, three gesture interactions (tapping, sliding, and circular motion) were assessed at seven different body locations (wrist, forearm, shoulder, collarbone, torso, waist, and front pant pocket). Interaction with a BlackBerry cell phone was also included as a baseline. The interactions were conducted on both a male and female actor, from distance (~4-5 feet) and close-up (~12-18 inches) views. This combination of areas (3X7X2X2), plus the BlackBerry interactions, resulted in a total of 88 video-captured interactions with the controller. Each video sequence ranged from 6 to 20 seconds.

Once the survey was launched, participants were asked to view an individual interacting with the wearable device in public from both distance (Figure 17) and close-up views (Figure 18). The video playback features were restricted so participants were only allowed to view each video one time. The length of the close-up video was so brief (1-2 seconds) that it was looped five times so that participants did not miss the interaction. Following each video, the participants were presented with eleven, 5-point

Figure 17. Distance view of body placement of wearable controller in public setting

Figure 18. Close-up view of gesture interaction with wearable controller

Likert-scale questions to evaluate their perception of the interaction's acceptability in public. Please see Appendix C for the fully developed questionnaires. As noted, the evaluation was two-fold. Participants watched a video of the interaction at a distance view followed by a close-up view of the same gesture/body interaction. The first series of questions pertaining to the distance view were targeted at capturing opinions of the controller body placement, and the second series of questions pertaining to the close-up view were targeted at capturing opinions of the gesture interaction taking place at the respective body locations.

STUDY REFINEMENT 1

A pilot study was conducted to garner feedback and refine the study. The first survey deployed revealed that the survey was inordinately long in duration, approximately 1.5 hours. To reduce the survey length, it was decided that the survey could be conducted in two parts. This is reflective of the natural dichotomy of entities being measured: hand gesture and on-body interface location. Thus, the 5-subject pilot study was used to determine the preferred gesture-type. Four out of five individuals favored the sliding motion. The identified gesture was used to reduce survey size to assess only on-body locations using that specific gesture.

The pilot study also revealed that two of the on-body locations, shoulder and collarbone, were so closely placed that the majority of participants had a difficult time distinguishing between the two locations. Thus, it was considered good-practice to eliminate one of the positions to reduce viewer confusion. The shoulder placement was ultimately removed due to three supporting reasons: a) the pilot study results deemed the collarbone to be more of an acceptable location for an on-body controller, b) a study conducted by Gemperle et al. [29] displayed the collarbone area as being a recognized location for natural on-body technology placement, and c) the collarbone was considered to be a more manageable position for textile manufacturing/fabrication purposes as many name brand companies embroider their logo on the collarbone area of fashionable tee-shirts. This final consideration was supported by Georgia Tech Instructor and Fashion Designer Clint Zeagler.

Finally, the video sequences were randomized using a partially-balanced Latin Square algorithm to reduce an ordering effect.

STUDY REFINEMENT 2

A second pilot study was run to capture statistical significance regarding question relationship. If strong positive correlations arose, this was indicative of question redundancy and possible question elimination. If strong negative correlations arose, this could result in a potential measure for acceptability. This pilot study also gave preliminary results that were promising for hypotheses validation. This would have to be confirmed by the full study. The correlation matrices conducted on the data from 11 participant responses indicated that there was not enough significance to support question refinement, or elimination.

INCLUSION & EXCLUSION CRITERIA

For research significance, the participants surveyed were both men and women of legal consenting age (18 in The United States of America) who identified as being of American nationality. Participants acknowledged this exclusion criterion by reading the consent form and entering their age and classifying nationality in the demographic questionnaire. Those who did not identify as being of American nationality were excluded due to the study intent of capturing culture-specific data. Minors were excluded from the study due to their natural familiarity with technology. This research looked to gain feedback from a larger cohort who has, admittedly, a broader level of exposure to, and experience with, the gamut of technological developments.

Additionally, it was important to establish full participant comprehension of the wearable control system in use. Thus, a qualifying question was administered after the survey introduction to assess a participant’s cognizance of what a textile-based wearable controller was. Those participants who still expressed confusion regarding what a wearable controller was (responding “No”, or “I don’t know”) were disqualified from the study.

CHAPTER 5

RESULTS

UNITED STATES OF AMERICA

Two pilot studies were performed prior to conducting the full study. The pilot studies were used to conduct statistical analysis and to refine the final survey structure and content prior to deployment.

PILOT STUDY 1

The first pilot study was conducted to determine the preferred hand-gesture motion (tapping, sliding, circular motion) for operation of the wearable device. The survey depicted videos of interactions of the wearable system at seven on-body locations (with Blackberry as a baseline), on both a male and a female, from both close and distance views.

Five individuals were recruited for the pilot study: 3 males, 2 females, age range 24-59. The pilot study determined that the preferred hand motion was sliding (4 votes), followed by tapping (1 vote) and then circular motion (0 votes). This finding was used to eliminate the videos with the remaining hand motions (tapping and circular motion) to avoid redundancy and participant exhaustion.

PILOT STUDY 2

The second pilot study was run to capture statistical significance regarding question relationship. Eleven participants were recruited for this pilot study: 8 females, 3 males, ages 20-59. Correlation matrices were conducted on all variables within gender and viewing distance to quantify areas where strong relationships amongst question-type existed. From the results, 46.4 % of the ratings between “Normal” and “Awkward” interactions revealed a strong negative correlation of $p < .01$, indicating that this pairing could be used to establish a potential measure of acceptability. Variables “Normal” and “Natural”, “Weird” and “Silly”, “Weird” and “Embarrassing”, “Bothers me” and “Embarrassing”, and “Bothers me” and “Weird” all reported strong positive correlations, indicating that one or more of these variables could be eliminated as they account for similarity of response type. Ultimately, the frequency of statistically significant correlations was not high enough to warrant question refinement.

This pilot study shed light onto what gestures and control body placements were most natural and most awkward. Figure 19 demonstrates that the wrist and the forearm were considered the two most normal locations for wearable controller placement (discounting the BlackBerry scenario, which, as expected, received the highest normalcy rating). As displayed in Figure 20, the pocket, torso, and the collarbone were all considered to be the most awkward body locations for wearable controller placement.

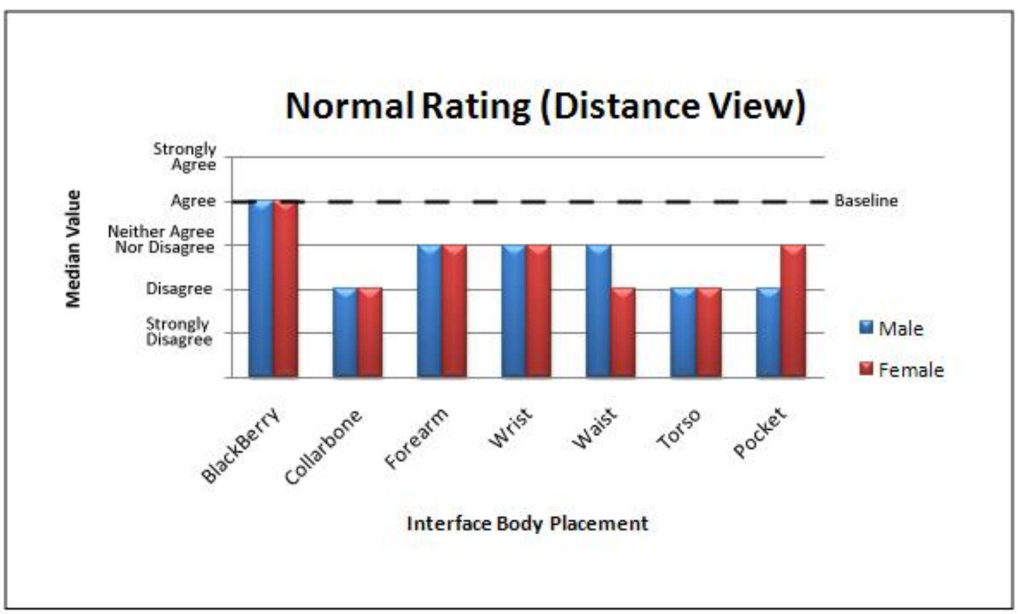


Figure 19. Pilot median scores of “Normal” rating for interface body placement

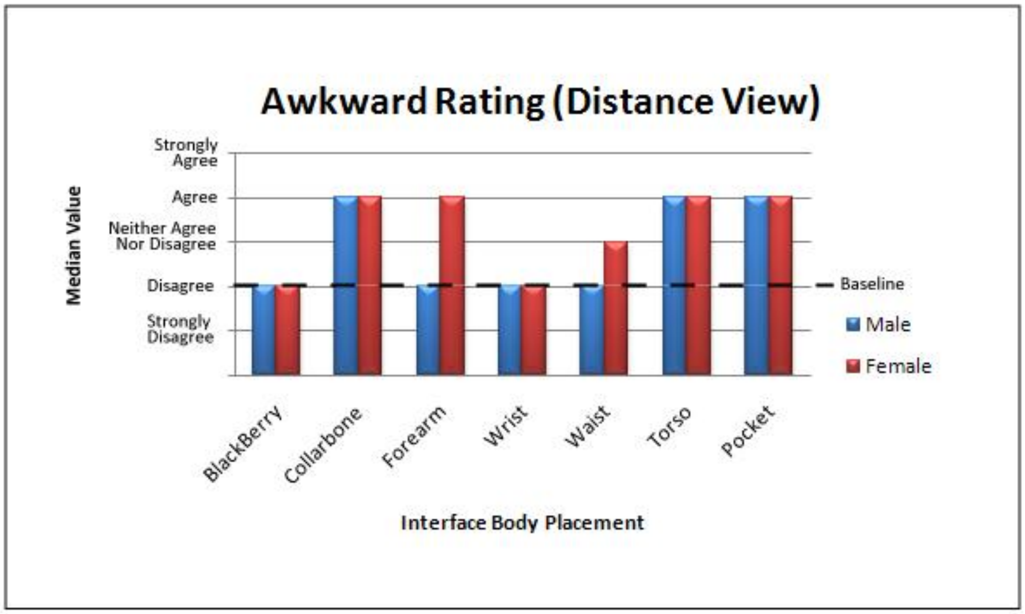


Figure 20. Pilot median scores of "Awkward" rating for interface body placement

The second pilot study also revealed that additional data, such as an individual's occupation, level of technical expertise, and their technology adoption rates, would be of relevance to the study. Thus, some additional questions to capture this data were developed to be included in the final survey.

STUDY RESULTS

Fifty-six participants were recruited for this study. Thirty-four of the participants were female and 22 of the participants were male. Participant ages ranged from 18 to 76. Participants were asked to complete a demographic questionnaire, the wearable technology acceptability survey, as well as an exit questionnaire that captured follow-up attitudes with regard to wearable technology usage. The results are discussed in the following section.

The data recorded attitudes toward the placement of the controller on the seven on-body locations (six locations and a BlackBerry control): wrist, forearm, collarbone, torso, waist, and front pant pocket, as well as attitudes toward viewing location-specific gesture interactions. The data indicated that of the six locations, forearm and wrist were considered the most “Normal” body locations for interface placement. Figure 21 demonstrates the median values of each body location. A BlackBerry served as a baseline for mobile computing usage that is currently deemed socially acceptable. Median values are reported instead of the mean because the data is non-parametric.

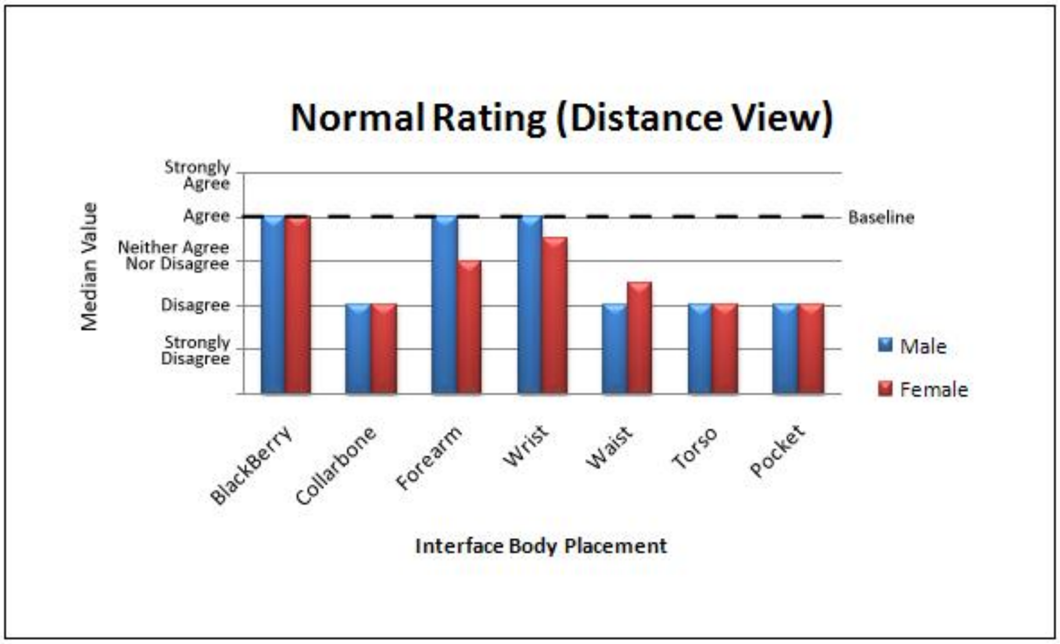


Figure 21. Median scores of “Normal” rating for interface body placement

Participant responses for the location-specific gesture interactions had similar findings with respect to wrist. Gesture interactions at the forearm and waist received the next highest “Normal” ratings as demonstrated in Figure 22.

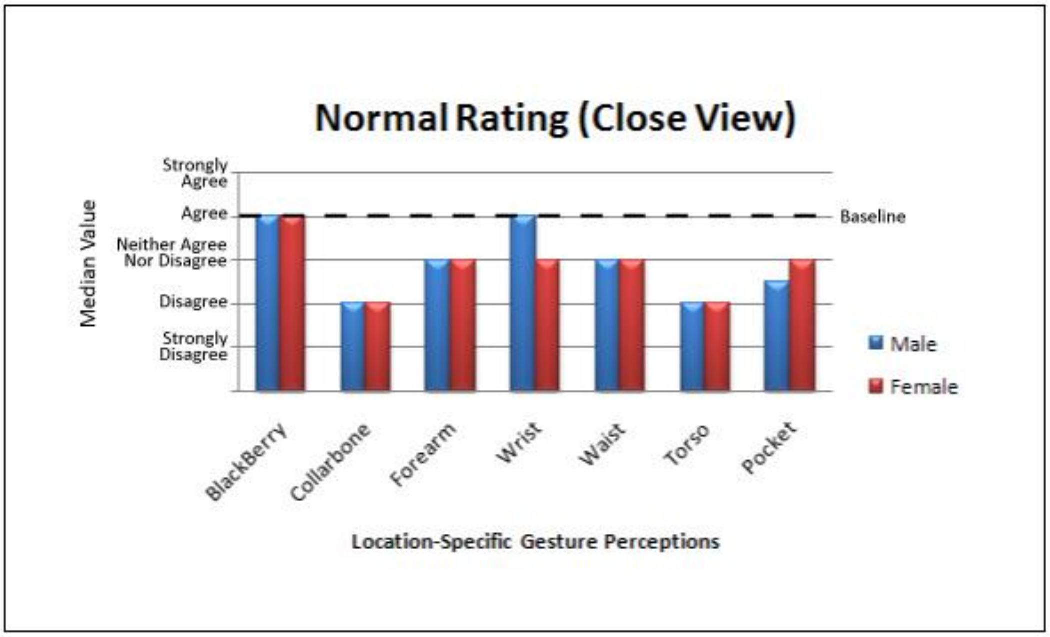


Figure 22. Median scores of "Normal" rating for sliding gesture per location

Participant responses to the "Normal" question were most strongly countered by responses to the "Awkward" question. Participants perceived the collarbone, torso, and pocket as the most awkward on-body locations for the wearable controller. The forearm and wrist locations received the same minimal awkwardness rating as the BlackBerry with respect to controller location and gesture interaction as the BlackBerry (see Figures 23, 24).

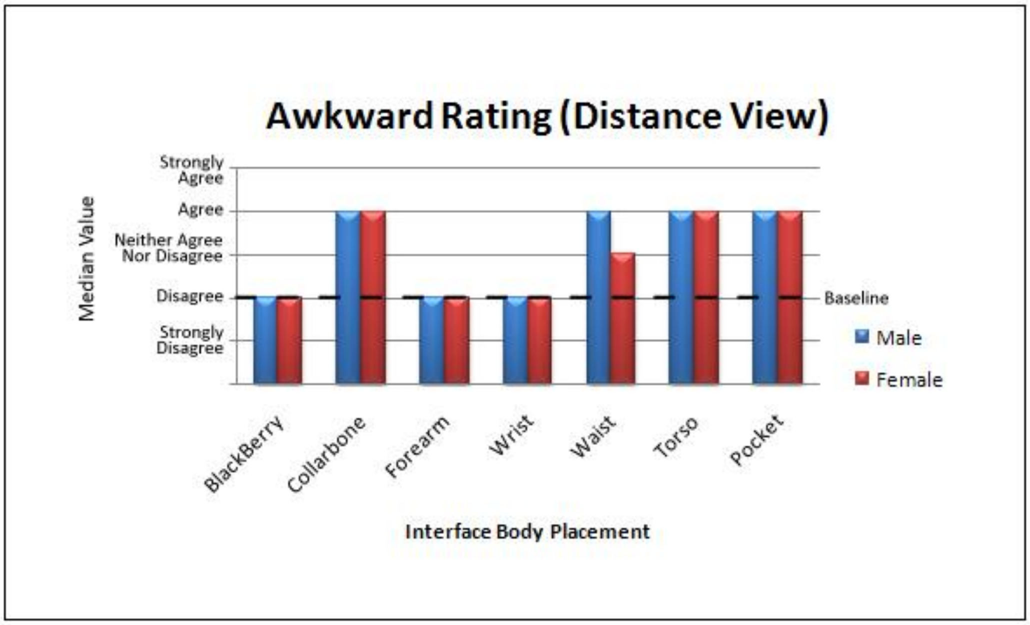


Figure 23. Median scores of "Awkward" rating for interface body placement

In fact, when comparing the graphs for "Normal" body location and "Awkward" body location at distance view, one can see that the location-specific value ratings are almost directly reciprocal of each other. Participant attitudes of awkwardness toward the sliding interaction at respective body points were consistent with those attitudes of awkward controller placement at the torso, and to a smaller degree awkward controller placement at the collarbone and pocket. Once again, the gesture-specific locations with the lowest "Awkward" ratings are the forearm and the wrist, which are consistent with the low "Awkward" rating for the BlackBerry. Attitudes of awkwardness with respect to the pocket were very divided when viewed on a female versus when viewed on a male.

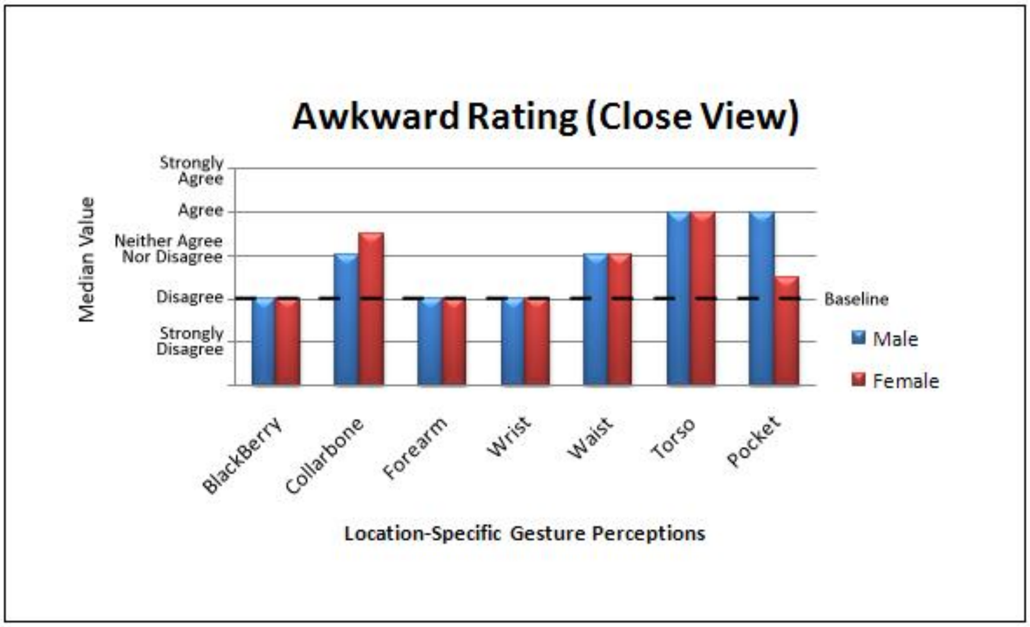


Figure 24. Median scores of "Awkward" rating for sliding gesture per location

Ratings for which body placement of the controller bothered people the most corresponded to those placements that received the highest awkward rating, but to a lesser degree (see Figure 25).

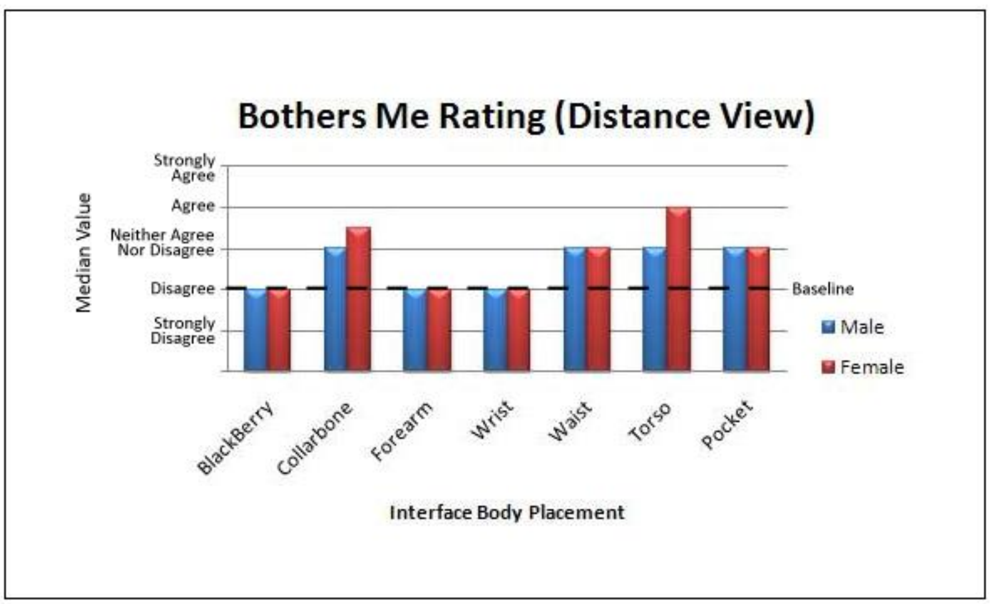


Figure 25. Median scores of "Bothers Me" rating for interface body placement

Figure 26 shows that of the body placements identified, most locations received the exact same rating regarding ease with which they were accessed. This is a necessary factor for assessment considering that device accessibility is a defining characteristic of wearable technology adoption. Given that all access points are relatively equal, this factor can serve as a constant by which all other attitudes are assessed. This can help us establish the higher level societal perceptions that will have a direct influence on location-specific controller interaction acceptability. Rightly so, a more indicative factor of acceptance, or lack of acceptance, was not the accessibility of the controller, but the added level of irritation that accompanied reaching that body placement. Figure 27 demonstrates the body placements that were deemed the most annoying locations to access, regardless of the level of reach ease that accompanied all of them. The reported values of “Annoyance” that resulted from accessing the collarbone and the torso correspond to the reported level of “awkwardness” for the same body locations.

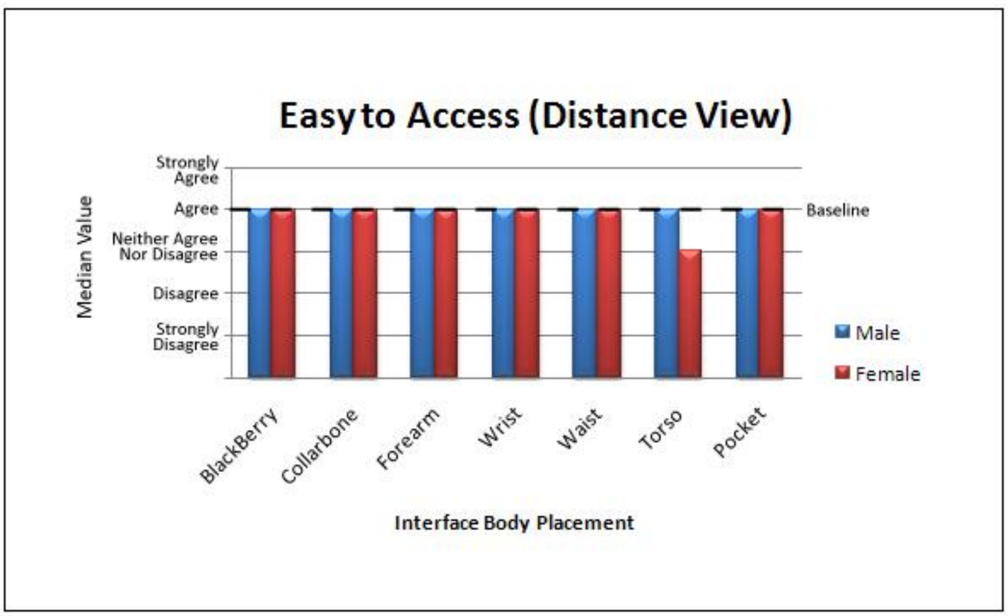


Figure 26. Median scores of “Easy to Access” rating for interface body placement

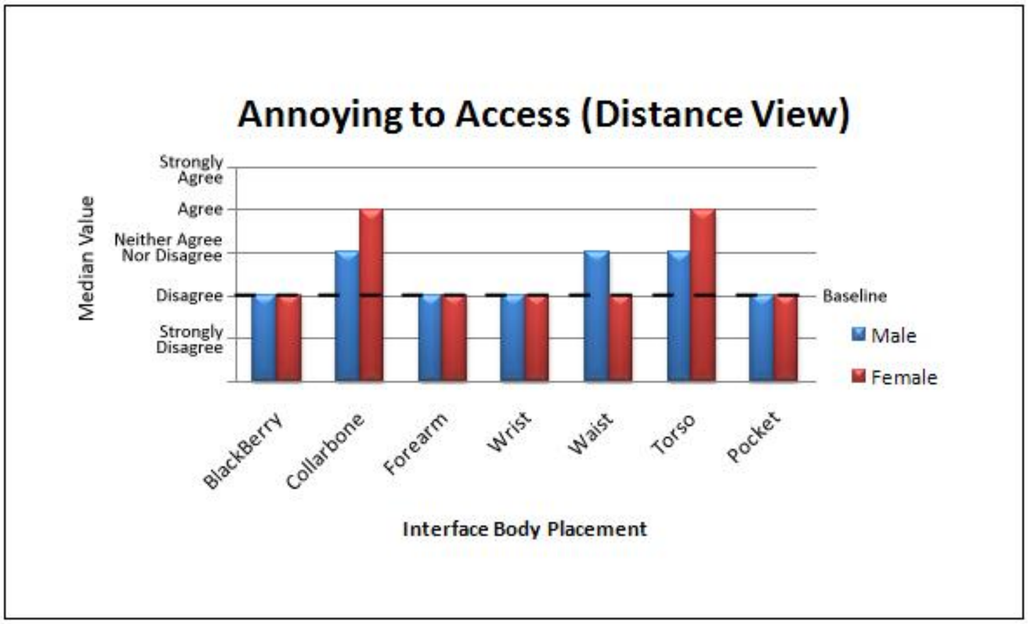


Figure 27. Median scores of "Annoying to Access" rating for interface body placement

Closer inspection of the gesture interaction occurring at each body location also reveals that collarbone, torso, and pocket were perceived as the most "Weird" locations for the sliding-based gesture interaction (refer to Figure 28). This reinforces the negative social attitude toward the collarbone, torso, and front pant pocket positions.

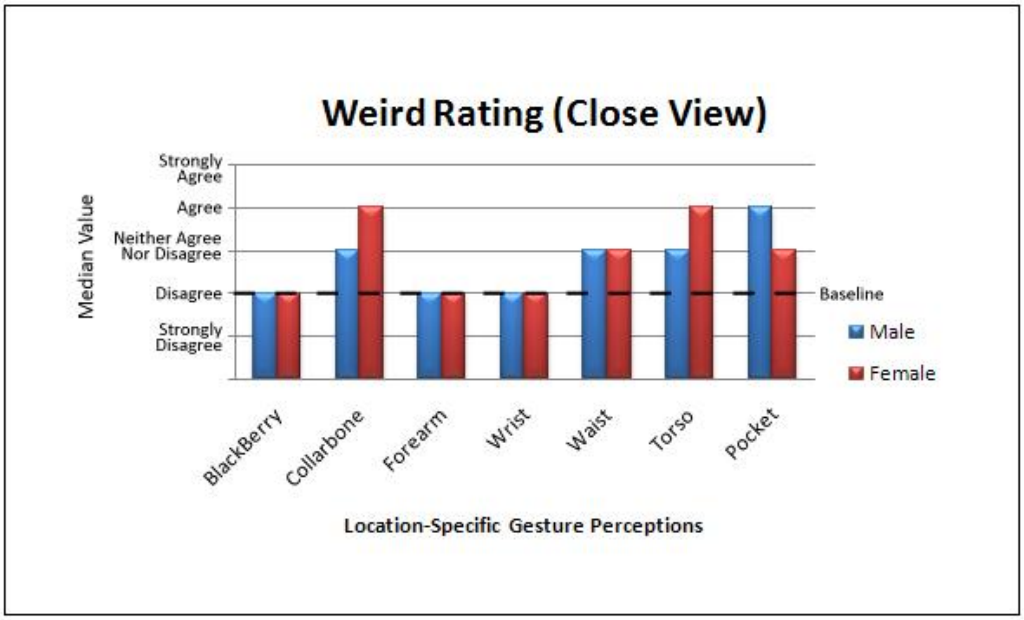


Figure 28. Median scores of "Weird" rating for sliding gesture per location

A Wilcoxon signed ranks sum test was performed on the data to determine if societal perceptions of body controller placement and location-specific gesture interactions differed when viewed on a male actor versus a female actor. Table 1 depicts the significant variability in perceptions of interaction type with respect to actor gender.

Table 1: Variability of controller placement perceptions based on actor gender

Interface Interaction	Significance	Mean Male	Mean Female
BlackBerry interaction looks natural from afar	.040	3.59	3.77
BlackBerry button pressing looks awkward from close-up	.017	2.45	2.73
Collarbone controller placement looks natural from afar	.019	2.57	2.36
Collarbone sliding motion looks cool from close-up	.024	2.57	2.36
Forearm controller placement looks easy to access from afar	.027	3.88	4.07
Forearm controller placement looks cool from afar	.004	3.11	2.84
Torso controller placement looks embarrassing from afar	.000	3.04	3.61
Torso controller placement bothers me from afar	.036	3.09	3.36
Torso sliding motion looks silly from close-up	.042	3.20	3.48
Torso sliding motion bothers me from close-up	.021	2.90	3.20
Torso sliding motion looks impolite from close-up	.000	2.43	2.93
Torso sliding motion looks weird from close-up	.002	3.21	3.70
Torso sliding motion looks embarrassing from close-up	.000	2.78	3.29
Pocket controller placement looks cool from afar	.018	2.52	2.71
Pocket sliding motion looks award from close-up	.000	3.45	2.88
Pocket sliding motion looks silly from close-up	.015	3.13	2.84
Pocket sliding motion bothers me from close-up	.010	2.91	2.66
Pocket sliding motion looks impolite from close-up	.007	2.86	2.59
Pocket sliding motion looks weird from close-up	.014	3.21	2.89
Pocket sliding motion looks natural from close-up	.005	2.71	3.00
Pocket sliding motion looks cool from close-up	.010	2.52	2.82
Pocket sliding motion looks normal from close-up	.001	2.64	3.00
Pocket sliding motion looks embarrassing from close-up	.046	2.89	2.68

Results show that in general, interactions with the controller on the front pant pocket was less socially acceptable when performed on a male, and interactions with the torso were less socially acceptable when performed on a female. Some other interesting points were that forearm controller placement looked significantly less cool on a female than on a male, whereas pocket controller placement looked significantly less cool on a male than on a female.

Additionally, a Mann-Whitney test was performed between subjects to determine if there was significant gender bias amongst participants of controller interaction acceptability. The significant results, compiled in Table 2, revealed that women found interactions that took place on the pocket and interactions that took place on the torso to be more bothersome than men. Women were also less accepting of the interactions that took place on the forearm than the male participants.

Table 2: Variability of controller placement perceptions based on subject gender

Interface Interaction	Significance	Mean Rank Male	Mean Rank Female
BlackBerry button pressing performed by a female from close-up looks weird	.047	24.23	31.26
Collarbone controller body placement on a male from afar looks comfortable to access	.036	23.16	31.96
Collarbone sliding motion performed by a male from close up looks normal	.019	22.82	32.18
Collarbone controller body placement on a female from afar looks awkward	.012	34.73	24.47
Forearm controller body placement on a male from afar looks awkward	.027	23.23	31.91
Forearm controller body placement on a male from afar looks easy to access	.031	33.48	25.28
Forearm sliding motion performed by a male from close-up looks easy to perform	.022	33.93	24.99
Forearm sliding motion performed by a male from close-up looks tiring	.041	23.84	31.51
Forearm controller body placement on a female from afar looks annoying to access	.041	23.84	31.51
Forearm sliding motion performed by a female from close-up looks easy to perform	.023	33.45	25.29
Forearm sliding motion performed by a female from close-up looks tiring	.045	24.09	31.35
Wrist controller body placement on a male from afar looks easy to access	.006	33.95	24.97
Wrist controller body placement on a female from afar looks easy to access	.037	33.16	25.49
Waist sliding motion performed by a male from close-up looks impolite	.039	23.45	31.76
Waist sliding motion performed by a female from close-up looks natural	.031	33.98	24.96
Torso controller body placement on a female from afar bothers me	.013	22.07	32.66
Torso sliding motion performed by a female from close-up bothers me	.002	20.57	33.63
Torso sliding motion performed by a female from close-up looks natural	.024	34.07	24.90
Pocket sliding motion performed by a male from close-up looks tiring	.023	23.25	31.90
Pocket sliding motion performed by a female from close-up bothers me	.008	21.75	32.87
Pocket sliding motion performed by a female from close-up looks tiring	.042	23.73	31.59
Overall, the sliding motion looks impolite	.007	22.86	32.15
Overall, the sliding motion looks embarrassing	.014	22.60	31.34

After responding to the series of acceptability questions, participants were asked additional attitude questions regarding the textile-based mobile controller in an exit questionnaire. Of participants surveyed, 85.7% found the controller to be “Very Useful” or “Useful”, and 62.5% indicated that they would be “Very Willing” or “Willing” to use a controller such as this one. When asked to select two preferred body locations for the wearable controller, wrist and forearm were the most favored, with wrist receiving 43 votes and forearm receiving 33 votes. This corresponds to acceptability ratings reporting wrist and forearm to be the most normal positions for a wearable controller. Of the body placement preference options, 51.8% of the respondents attributed the “easy to access” feature as being the reasoning behind their choice. This was broken down even further by gender. Table 3 illuminates the two preferred body locations for the controller with respect to gender. As one can see, the wrist and the forearm were preferred by both male and female participants

Table 3. Participant gender preferences for controller body placement

	Wrist	Forearm	Waist	Collarbone	Front Pocket	Torso
Female	30	20	8	1	9	0
Male	13	13	6	3	8	1

When asked to select the two most non-preferred body locations for the wearable controller, torso and collarbone reported the highest count with torso receiving 39 votes and collarbone receiving 33 votes. Notably, when asked to describe the reasoning for these non-preferred body locations, 71.4% reported that they viewed the positions as “awkward” or some variation of “weird”, “embarrassing”, or “strange”. When asked to indicate the two most important features of a wearable system, participants reported that the device should be “easy to access” and that it “should not make the user look awkward or weird.” Other strongly weighted features were “can use (controller) without looking”, “easy to operate”, and “can move (controller) between other items of clothing”. When asked to select a variety of tasks users would most likely use the controller for, 48 individuals indicated a cell phone interaction, 36 reported a MP3 player, and 15 were interested in using the system to lock and unlock a door.

RESULTS OF THE HYPOTHESES

Hypothesis 1 states that participants will define a set of body placements for acceptable locations of the textile-based wearable controller. Of the participants surveyed, wrist and forearm are the two highest rated and preferred gestures for body controller placement.

Hypothesis 2 states that wrist and forearm will be the most acceptable body locations for interface placement. This hypothesis is based on the pre-established usage and acceptability of the wrist and arm for current wearable technology. The data from both the acceptability ratings and the exit questionnaire confirm this hypothesis.

Hypothesis 3 states that the acceptability ratings of controller body placements will differ based on gender of the performer. As such, significant differences of body placement acceptability were not found across every location with respect to gender, however, areas such as the pocket and torso did have numerous points that indicated that actions on the pocket were less socially acceptable when performed on a male, and actions on the torso were less socially acceptable when performed on a female.

Hypothesis 4 states that the preference of controller body placement will differ based on participant gender. For females, wrist was the preferred location followed by the forearm location. For males, the wrist and forearm body locations were tied with the number of preferred counts. Thus, this statement is unsupported. For more definitive results there may need to be an equal number of male and female responses for this condition.

Hypothesis 5 states that participants will define the most preferred input gesture for a wearable controller. With respect to the individuals surveyed, the majority-preferred gesture is sliding.

Hypothesis 6 states that input gestures that demand a perceived level of minimal attention will be preferred. This statement is supported, as participant open responses from pilot study one indicated that the circular motion was not preferred as one “wouldn’t know where to start and stop” without looking, and that tapping might result in accidental triggering (where one can assume that you would have to take additional precautions to not mistakenly activate the device).

Hypothesis 7 states that input gestures that are quicker to perform will be preferred. This claim could not be supported, as the tapping motion was the quickest motion to perform.

CHAPTER 6

DISCUSSION

LIMITATIONS OF THE STUDY

Some technical aspects arose that were identified as limitations within the study. While surveying is an ideal method for conducting large-scale studies, there are a number of environmental factors, such as light, ambient noise, and survey completion time that remain out of the control of the experimenter. With regard to this study, there was no way to ensure that a participant had watched the actual videos before completing the corresponding questions. Additionally, there were instances where a participant would try to proceed to the next page in the survey without having completed all of the questions for the current page. In such a case, participants were instructed to complete the questions before being permitted to move to the next page. This warning would refresh the current survey page, reloading the videos and giving participants the chance to watch the videos a second time. The frequency of this occurrence could not be recorded. Furthermore, as noted in the Study Parameters section, participants recruited were required to adhere to the inclusion/exclusion criteria. There was, however, no way of ensuring that participants truthfully responded to the screening questions.

REFLECTION ON THE RESULTS

The data was able to define a clear gesture palette and body locations for acceptable technology interaction. For the acceptability survey, participants were asked 11 repeated 5-point Likert-scale acceptability questions (ranging from "Strongly Disagree" to "Neither Agree nor Disagree" to "Strongly Agree") for the respective video scenarios. Due to the fact that such little research has been done within the area of mobile technology assessments with respect to social acceptability, there was very little precedent for what qualifies as a measureable format for acceptability. With no definitive metric in place, this research asked as many qualifying emotional response questions to garner insight into how society at large deemed actions acceptable or unacceptable. Furthermore, there was no included definition of terminology. This was intended to allow public opinion to drive the definition of the vocabulary used, such as “Normal”, “Awkward”, “Impolite”, et cetera. Hence, while the term “Normal” may have different meanings to different people, this research looked to capture if a generalized attitude of normalcy with respect to wearable technology interaction surfaced.

The first pilot study revealed that the sliding motion was gesture method that was preferred by the majority of participants. Participants described this motion as being “discreet”, “fast”, seeming “intentional”, and making “significant contact”. They reported accidental trigger concerns with respect to the tapping motion, and opined that the circular motion looked “cool” but seemed harder to use.

The first pilot study also helped reduce the number of on-body positions from 7 to 6. Participants considered the shoulder and collarbone placements to be hard to distinguish since they were so closely located. Eliminating the shoulder location was the justifiable solution as the collarbone area supports embroidery work as well as a natural interaction that takes place with one’s shirt collar. Yet, in retrospect, repositioning the shoulder location to the upper arm region would yield an interesting comparison between preferred controller arm locations. Karrer et al. [38] looked at an eyes-free textile input system and determined that individuals preferred interacting with the system on the lower portion of the arm. For their study, however, they chose to use the upper arm for system positioning as not all clothing items will cover the entire length of the arm. Discerning the strengths and weaknesses of these placements is cause for future research.

The second pilot study was conducted to determine if the acceptability questions could be refined to reduce survey length. Correlation matrices were used to assess response similarity. Of the analyses performed, no statistically significant correlations could be gleaned. However, the survey did help yield insight into additional demographic and follow-up questions that would deliver interesting results for cross-comparison.

The final survey data returned invaluable information regarding the societal perceptions of the different on-body location interactions being studied. As expected, the most “Normal” rated on-body positions for the textile controller interface were the wrist and forearm. These positions were illuminated in Hypothesis 2, and are supported by related research [38]. The controller body placements deemed most “Normal” from the acceptability evaluation are also supported by the body placement preferences asked of participants in the follow-up questionnaire. These results indicate that the term “Normal” is a good indicator of what is deemed acceptable by society.

Furthermore, the wrist and the forearm, along with the BlackBerry, received the lowest overall median scores with respect to the “Awkward” rating. This reinforces the wrist and the forearm as being the two most socially acceptable on-body positions for a controller. Furthermore, the on-body locations that received the highest “Awkward” rating were the collarbone, front pant pocket, and torso. This is reinforced by the follow-up questionnaire where the majority of participants responded that the two least likely positions they would consider using a wearable controller are the collarbone and torso.

This, in turn, reveals that connotatively, the term “Awkward” can serve as a good measure for what is least socially acceptable. It also sets the stage for the possibility of creating a measure of social acceptability with respect to novel technology interactions. For this to occur, however, the study would need to gather more participant responses.

Median values of other terms correlated closely to the “Awkward” rating. “Silly” and “Weird” received very similar scores as “Awkward” with respect to the on-body placement of the controller. These terms could also be of value when exploring the possibility of creating a standardized social acceptability measure.

82.7% of the participants indicated that they would find the device to be “Very Useful” or “Useful”, and 62.5% indicated that they would be either “Very Willing” or “Willing” to use a controller such as this. According to du Gay, such positive reflections toward product usage is important, because no matter how much we might like it if we see it, if we cannot imagine ourselves using it, then we will be more reluctant to acquire it [4]. Due to a majority of users who seem interested in this type of technology, it is warranted to say that many individuals in this day and age may be receptive to the idea of an easily accessible, on-body controller that can interact with external devices in a manageable fashion. There were a number of ways that users indicated they would use the controller, namely, interacting with a cell phone, mp3 player, locking and unlocking a car door, and interacting with a television. The first three listed represent interactions that would take place in very mobile occurrences, indicating that a controller such as this would be preferred to help support a traveling lifestyle.

With respect to preferred body placement locations, wrist and forearm were the most popular, with practically double the preferences than any of the other body locations. Such a response is understandable since the wrist is a pre-established area for wearable technology (the wristwatch) and has been ingrained in society as an accepted body location since wartime 1940s [8]. An element adding to the popularity of the wrist and the forearm locations are that they are easily visible.

While it was clear that participants reported preferring a device that was minimally visually demanding, it can be assumed that the ability to see the controller when desired to ensure accurate operation. Many of the responses listed lack of visibility as a limitation of the other body placement controller positions. Of further interest was the open response section that succeeded the preferred body location questions.

Participants were asked to describe their reasons behind their body choice preferences. In open response, over 50% of the participants indicated that the positions that they chose were due to the fact that those locations were “easy to access”. This is a very significant response as accessibility is one of the leading characteristics that has proven central to successful wearable technology usage.

Furthermore, participants were asked to choose two body locations deemed non-preferable. As mentioned before, the two areas selected were the torso and the collarbone. These selections are consistent with the overall high awkward ratings reported for these two areas. The pant pocket received an equally high awkward rating but was reported as being the 4^{th} non-preferred body placement. This can perhaps be attributed to the front pocket controller location with respect to our hands, which fall naturally to the height of our pant pocket, thus requiring less effort to access. Another supporting factor of the negative response to the collarbone over the pant pocket is the noticeability of the interaction at that location. A discreet interaction with the pant pocket would be marginally noticeable; however, interaction with the collarbone would be largely conspicuous and undesirable if it required constant use.

Furthermore, the size of the controller in relation to the collarbone could be another discordant factor. Finally, as consistent with a previous argument of visibility, participants might be less accepting of the collarbone area as it does not permit visibility. The pant pocket is beyond eye-sight, but should a participant need to look down and view the device, the location of the pant pocket provides for this ability where the collarbone does not. The follow-up descriptions were of extreme interest. Once again, participants were asked open-ended responses for why they chose the two body locations. Of the responses, 71.4% described the selected body locations to be a variation of “awkward” “weird” or “strange” in nature. This is highly indicative of a response that corresponds to a measure of acceptability. These participants followed many of their “awkward” claims with statements such as, “would add bulk and call attention to already too obvious body parts,” and “it would feel awkward to me to touch my torso to use a controller”. These statements describe the body placement and corresponding motion, indicating that the entire interaction is something that users are unwilling to partake in. Such a strong response shows the significance of a product interaction being acceptable for it to be adopted by users. This statement is also supported by the exit questionnaire where participants indicated that one of the two most important features of a piece of wearable technology is that it does “not make the user look awkward or weird.”

Special attention was also given to disparities of perception with respect to device placement on both a man versus a woman. Close-up views received the most drastically divergent attitudes. Referring to Table 1, one can see that interacting with the controller from close-up looked significantly more weird, impolite, embarrassing, bothersome, and silly on the female actor than it did on the male actor. Furthermore, interactions that took place with the pocket from a close view looked significantly more silly, bothersome, weird, impolite, and embarrassing on a male than on a female.

It was of interest to see how divided participants were regarding controller placement and device interaction between genders. Points of interest revolve around the collarbone, torso, and pocket. Referring to Table 2, women, in general, felt that interactions with the pocket looked more tiring and bothersome. Women in general also considered interactions with the torso to look more bothersome when performed on a female. Women, in general, also felt that interactions with the collarbone looked more comfortable and normal when performed by a male, whereas men felt that interactions with the collarbone looked more awkward when performed by a female. Men also perceived interactions with the controller on the forearm more positively than females did. Overall, males felt that the forearm interactions looked easier to access and easier to perform. Females, on the other hand, considered the forearm interactions to be slightly more annoying to access and tiring when performed. This feedback is unaccounted for as it opposes the overall acceptability ratings of controller body placement at the forearm, but it does pose interesting areas of further exploration with respect to gender preferences.

FINAL EXPOSÉ

This research demonstrates significant insight into the social acceptability of a wearable, textile-based mobile system. While this study has yielded pertinent criteria to consider in the possible design and implementation of wearable systems, some points must be made with respect to the overall results. The results are specific to the textile controller interface, body placements, and gesture interactions used in this study and therefore cannot be generalized for all types of wearable, textile interface interactions. As such, the results are also specific to the attire used in the study. As such, this research cannot speak to the social acceptability of controller usage on clothing items that might cover the same area of the body but are in fact different, e.g. a skirt or a scarf. Controller design, body placement, interaction type, and integration method are all highly variable in nature and thus can differ significantly with respect to what is socially acceptable. Furthermore, the results of this study can only speak to the social acceptability of interactions with this controller interface at this point in time. Due to the fact that social acceptability is constantly changing, this research may not hold true 5 or 10 years from now. What this research sought to capture is a snapshot of the current societal perceptions regarding wearable technology placement and usage. In light of this, social acceptability research within the field of wearable technology should be continued with respect to novel interface designs and body placement for a broad range of classifiable elements to serve as an aid for informed design for wearable technologies.

FUTURE WORK

Due to the fact that social acceptability is culturally driven, we intend to explore this question in greater detail with respect to different countries. Thus, this study will be conducted in India and Korea, as these countries were chosen for their strong presence in the technology industry. Korea garners specific attention as this country has a vested interest in the development of wearable technologies.

As such, we hope to find strong cultural differences in what qualifies as acceptable wearable technology interaction behavior. This would signify the presence of cultural bias as a deterministic factor in the adoption rates of new technologies. We hope to show how cultural perceptions will be an essential element for making informed design decisions in the creation of successful wearable technology outcomes.

Beyond these culture studies, this research sets the stage for a large range of promising next-generation social and technological work within the space of wearable technology. Interface design will be one of the greatest challenges for the field of wearable computing [24]. As such, one can iterate on this technology to devise novel interface and integration conditions. These iterations could be evaluated on a number of levels, such as social acceptability, wearability, and usability issues. This research could also be furthered by exploring new gesture palettes or assessing the various function/design tradeoffs accompanied by electronic textiles.

Long-term evaluation of these technologies in use would be another interesting and pertinent avenue to explore, as this will pose a significant question regarding the adoption rates and serviceability considerations of these technologies in our daily lives.

This would also help assess how socially acceptable these controllers become with prolonged exposure to society at large.

Perhaps one of the most suitable conditions for wearable technology to blossom is that of the contextually-defined wearable technology space. Implementation of wearable technology in application-specific purposes can support activities that can greatly benefit from an on-body system while avoiding the underlying problem-set which restricts full-scale wearable technology realization. An example would entail profession-specific use such as law enforcement officers or Emergency Medical Technician (EMT) responders. Researchers could explore if interaction with the technology becomes acceptable within that specific domain, accounting for a useful, trainable, and easily recognizable set of socially accepted behavior that reduces the issue of technology transfer between different items of clothing.

Drawing from previous work done by Holleis et al. [28], and as a reflection on the results of this study, social acceptability should be further explored with respect to interface/gesture/location combinations. As discreet interfaces are preferred, conspicuous interactions with those interfaces are undesirable, as interaction intent is not clearly discernable to a third party. Likewise, a large and conspicuous on-body device might not always be preferred, yet it provides visual feedback for operation behavior that follows suit. Assessing the levels of social acceptability for each type of interface/gesture/location combination will help organize appropriate wearable technology applications and their corresponding usage criteria.

APPENDIX A: GUIDELINES FOR WEARABILITY [29]

Guidelines for Wearability:

1. Placement (where on the body it should go)

2. Form Language (defining the shape)

3. Human Movement (consider the dynamic structure)

4. Proxemics (human perception of space)

5. Sizing (for body size diversity)

6. Attachment (fixing forms to the body)

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7. Containment (considering what's inside the form)

8. Weight (as it spread across the human body)

9. Accessibility (physical access to the forms)

10. Sensory Interaction (for passive or active input)

11. Thermal (issues of heat next to the body)

12. Aesthetics (perceptual appropriateness)

13. Long-term Use (effect on the body and mind)

APPENDIX B: CONSENT FORM

CONSENT DOCUMENT FOR ENROLLING ADULT PARTICIPANTS IN A RESEARCH STUDY

Georgia Institute of Technology

Project Title: *Social Acceptability of Wearable Technology Use in Public: An exploration of the societal perception of a gesture-based mobile textile interface.*

Investigators: *Dr. Ellen Do (Principal Investigator), Clint Zeagler (Co-Principal Investigator), Halley Profita (Student Researcher), James Clawson (Student Researcher).*

Protocol and Consent Title: *Social Acceptability of Wearable Technology Use in Public: An exploration of the societal perception of a gesture-based mobile textile interface. (10/08/10 v1)*

Introduction:

You are being asked to be a volunteer in a research study.

Purpose:

The purpose of this study is to determine how socially acceptable it is when interacting with a wearable electronic fabric-based device at different points on the body. We expect to enroll 50 - 70 people in this study.

Exclusion/Inclusion Criteria:

This study is restricted to individuals ages 18 and older. You are being asked to participate in this study if you identify as being of American nationality.

Procedures:

This research will be conducted through an online survey. If you decide to participate in this study, we ask that you complete it within one sitting. The study should take approximately 25 minutes to complete. The survey will ask questions about your background and your feelings regarding interacting with technology on the body.

Risks or Discomforts:

There are no known risks or discomforts associated with participation in this research.

Benefits:

You are not likely to benefit in any way from joining this study. We hope that what we learn from this study will promote advances in wearable forms of fabric-based electronics.

Compensation to You:

There will be no compensation for participating in this study.

Confidentiality:

This research is being conducted via a web survey provider. Although you will not be asked your name, email, phone number or any other specific identifiers, you should be aware that the experiment is not being run from a 'secure' https server of the kind typically used to handle credit card transactions, so there is a small possibility that responses could be viewed by unauthorized third parties such as computer hackers. In general, the web page software will log as header lines the IP address of the machine you use to access this page, e.g.,102.403.506.807, but otherwise no other information will be stored unless you explicitly enter it.

Your name and any other face that might point to you will not appear when results of this study are presented or published. Your privacy will be protected to the extent allowed by law. To make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB may review study records. The office of Human Research Protections may also look over study records during required reviews.

Costs to You:

There are no costs to you, other than your time, for being in this study.

In Case of Injury/Harm:

If you are injured as a result of being in this study, please contact the Principal Investigator, Dr. Ellen Do at (404) 385-5041. Neither the Principal Investigator nor Georgia Institute of Technology has made provision for payment of costs associated with any injury resulting from participation in this study.

Participant Rights:

- Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
- You have the right to change your mind and leave the study at any time without giving any reason and without penalty.
- Any new information that may make you change your mind about being in this study will be given to you.
- You do not waive any of your legal rights by signing this consent form.

Conflict of Interest:

There are no known conflicts of interest related to this study.

Questions about the Study:

- If you have any questions about the study, you may contact Dr. Ellen Do at telephone number (404) 385-5041 or ellendo@gatech.edu.

Questions about Your Rights as a Research Participant:

- If you have any questions about your rights as a research participant, you may contact:

  Ms. Melanie Clark, Georgia Institute of Technology
  Office of Research Compliance, at (404) 894-6942.

By completing the online survey, you indicate your consent to be in the study.

APPENDIX C: QUESTIONNAIRES

Social Acceptability of Wearable Technology Use in Public: An Exploration of the Societal Perceptions of a Gesture-based Mobile, Textile Interface.

Study: H10314

Questionnaires

Demographic Information

1) What is your gender?
   - ☐ Male
   - ☐ Female

2) What is your age?_____________

3) What is your highest level of education?
   - ☐ Some High School
   - ☐ High School/GED
   - ☐ Some College
   - ☐ 2-Year College Degree (Associates)
   - ☐ Vocational/Technical Degree
   - ☐ 4-Year College Degree (BA,BS)
   - ☐ Master's Degree
   - ☐ Doctoral Degree
   - ☐ Professional Degree (MD,JD)

4) What is your current marital status?
   - ☐ Single/Never Married
   - ☐ Married/Partner
   - ☐ Separated
   - ☐ Divorced
   - ☐ Widowed
   - ☐ Prefer not to answer

5) What is your race?
   - ☐ White/Non-Hispanic
   - ☐ Black/Non-Hispanic
   - ☐ Hispanic
   - ☐ Asian/Pacific Islander
   - ☐ Native American
   - ☐ Multi-racial
   - ☐ Other:_______________

6) What is your occupation? (If you choose not to answer please write "prefer not to respond")

   ____

7) What is your nationality?

☐ American
☐ Indian
☐ Korean
☐ Other:_______________

Social Acceptability Measurement Questions

Do you understand what a wearable controller is?
☐ Yes ☐ No ☐ I don't know

The person's interaction with the phone.../The body placement of the controller...

1)Looks awkward.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagre

2)Looks normal.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

3)Looks silly.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

4)Looks easy to access.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

5)Bothers me.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

6)Looks comfortable to access.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

7)Looks embarrassing.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

8)Looks annoying to access.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

9)Looks weird.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

10) Looks natural.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

11) Looks cool.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

The button pressing.../The sliding motion.../The tapping motion.../The circular motion...

12) Looks awkward.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

13) Looks silly.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

14) Looks easy to perform.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

15) Bothers me.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

16) Looks impolite.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

17) Looks weird.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

18) Looks natural.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

19) Looks cool.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

20) Looks tiring.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

21) Looks normal.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

22) Looks embarrassing.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

Exit Questionnaire

23) Would you find a wearable controller like the one shown in this survey to be useful?

☐ Very Useful
☐ Somewhat useful
☐ Neither useful nor unuseful.
☐ Not very useful
☐ Not at all useful

24) Do you find the controller design to be fashionable?

☐ Yes ☐ No ☐ Impartial ☐ Other:____________________

25) How willing would you be to use a wearable controller such as this one?

☐ Very willing
☐ Somewhat willing
☐ Neither willing nor unwilling
☐ Not very willing
☐ Not at all willing

26) If you were to use a wearable controller, what are the two most important features that you feel the system should have? *(Please select only two)*

- ☐ Easy to access
- ☐ Easy to operate
- ☐ Doesn't interfere with movement
- ☐ Doesn't interfere with other items worn on body
- ☐ Can use without looking
- ☐ Is not very noticeable to others
- ☐ Can be moved between different pieces of clothing
- ☐ Doesn't make me look weird or awkward
- ☐ Other:______________________

27) What would you most likely use a wearable controller like this for? (Select all that apply)

- ☐ Interacting with an MP3 player
- ☐ Locking and unlocking a car door
- ☐ Turning the lights in a room on and off
- ☐ Interacting with your cell phone
- ☐ Interacting with a television
- ☐ Changing the room temperature
- ☐ Other:______________________

28) a. On which body location would you wear a controller like this one? *(Please select only two)*
- ☐ Forearm
- ☐ Wrist
- ☐ Torso
- ☐ Collar Bone
- ☐ Shoulder (*removed)
- ☐ Front pocket
- ☐ Waistline/Belt buckle

b. Please describe why:____

29) a. On which body location would you NOT wear a controller like this one? *(Please select only two)*
- ☐ Forearm
- ☐ Wrist
- ☐ Torso
- ☐ Collar Bone
- ☐ Front pocket
- ☐ Waistline/Belt buckle

b. Please describe why:____

Overall, the sliding motion...

30) Looks awkward.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

31) Looks silly.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

32) Looks easy to perform.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

33) Bothers me.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

34) Looks impolite.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

35) Looks weird.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

36) Looks natural.
☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

37) Looks cool.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

38) Looks tiring.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

39) Looks normal.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

40) Looks embarrassing.

☐ Strongly Agree ☐ Agree ☐ Neither Agree Nor Disagree ☐ Disagree ☐ Strongly Disagree

41) Would you have any concerns about using a wearable controller such as this one?

☐ Yes ☐ No ☐ I don't know

b. Please describe why:____

42) For how many years have you been using the following types of technology? *(If technology never used respond "0 years")*

Cell Phone:_________Years

Camera Phone:______Years

Smart Phone:_______Years

Laptop:____________Years

43) For how many years have you been using wearable technology? *Please list up to 3 types (ex. Camera on a lanyard – 5 years)*

1)_______________- _______Years

2)_______________-________Years

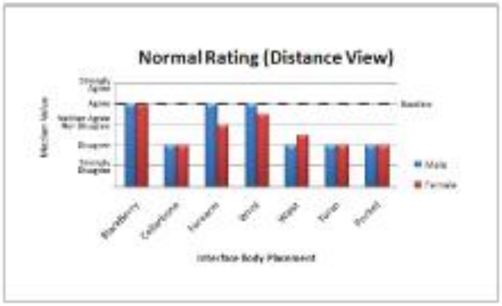
3)_______________-________Years

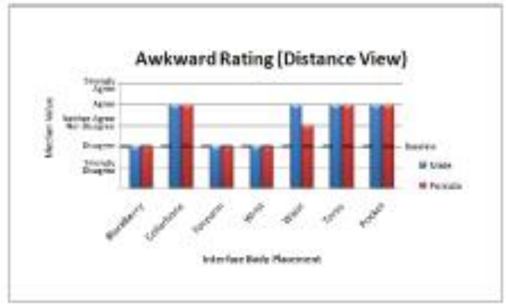
44) When a new piece of technology comes out on the market you...

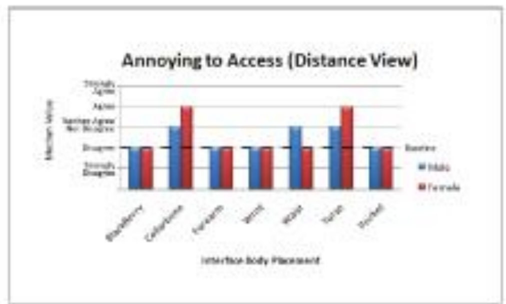
a) Order it before it even comes to market or wait in line the day before it comes out to purchase it.
b) Purchase it soon after it comes out - typically before a lot of people you know buy it.
c) Are interested in purchasing it but wait a little while until the hype has died down and more people you know have it.
d) Hold off on purchasing it until it has been around for a while and/or many people you know have it and like it.
e) Don't care about purchasing it unless it is absolutely necessary.

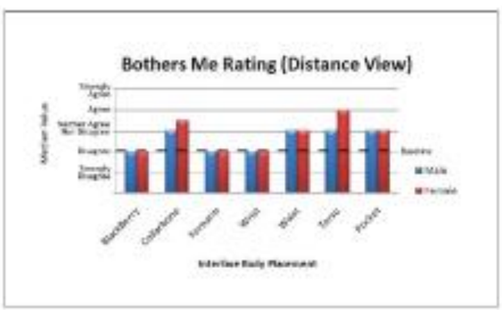
45) Additional Comments?____

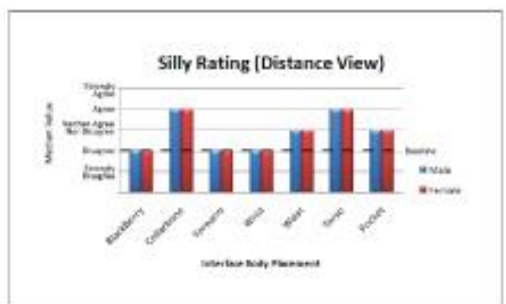
APPENDIX D: CONTROLLER BODY PLACEMENT AND GESTURE USAGE ACCEPTABILITY RATINGS

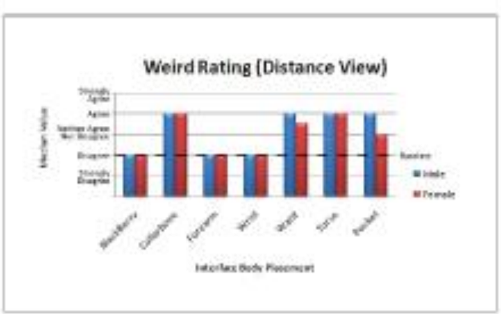


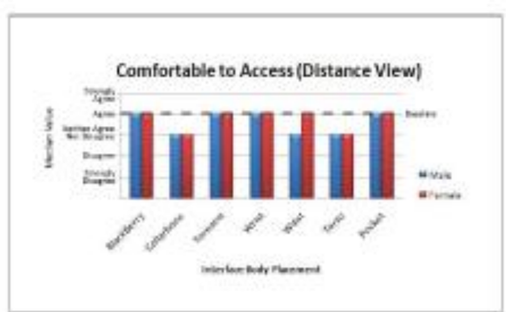


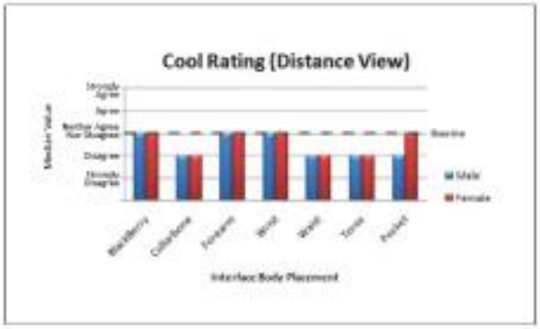


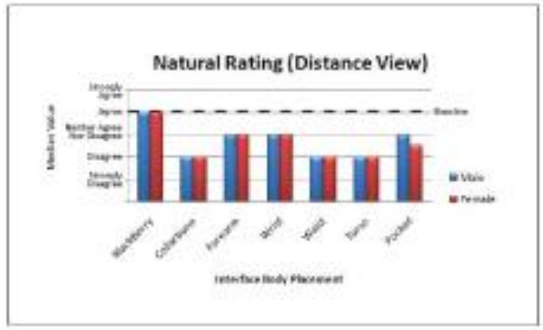


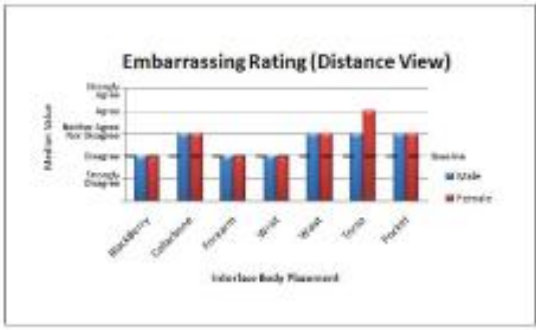


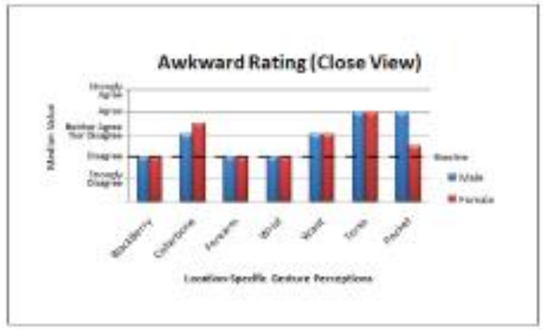


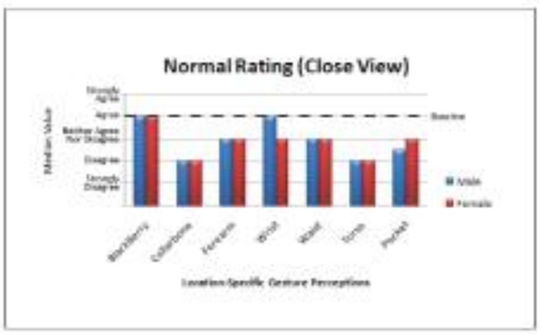



Cool Rating (Distance View)

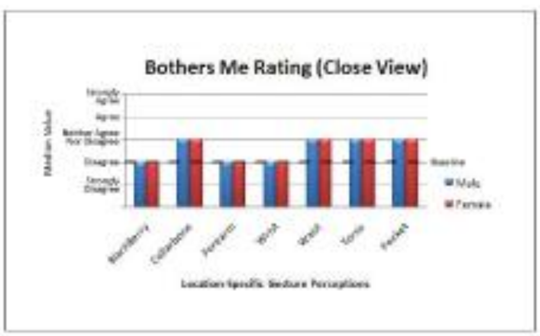

Natural Rating (Distance View)

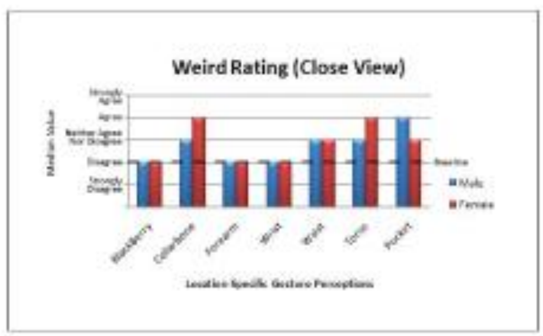

Embarrassing Rating (Distance View)


Awkward Rating (Close View)

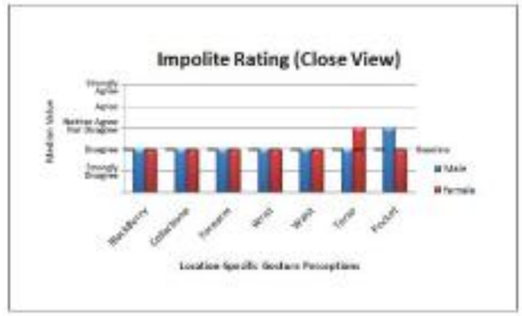

Normal Rating (Close View)

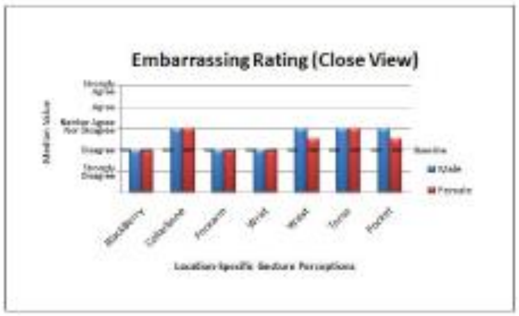

Silly Rating (Close View)

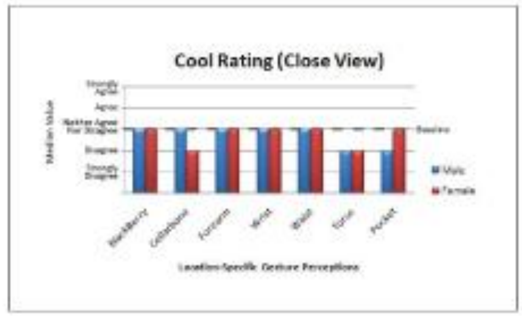

Bothers Me Rating (Close View)

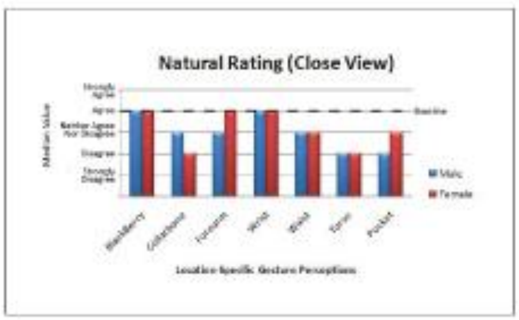

Weird Rating (Close View)

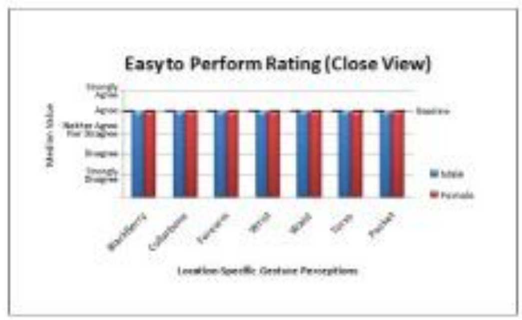

Tiring Rating (Close View)
Location-Specific Gesture Perceptions
Male
Female


Impolite Rating (Close View)
Location-Specific Gesture Perceptions
Male
Female


Embarrassing Rating (Close View)
Location-Specific Gesture Perceptions
Male
Female


Cool Rating (Close View)
Location-Specific Gesture Perceptions
Male
Female


Natural Rating (Close View)
Location-Specific Gesture Perceptions
Male
Female


Easyto Perform Rating (Close View)
Location-Specific Gesture Perceptions
Male
Female

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